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Essays on International Sustainable Development

Essais sur le développement international durable

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Essais sur le développement international durable

Résumé :

Cette thèse analyse des questions de développement international, en se concentrant sur les investissements directs étrangers (IDE), les inégalités sociales et la soutenabilité environnementale. À travers six essais, elle explore des dynamiques micro et macroéconomiques en utilisant diverses méthodes quantitatives pour aborder des thèmes tels que l'autonomisation des femmes, l'accès à l'énergie, l'industrialisation, et les effets environnementaux des IDE. Le premier essai examine l'impact de l'accès à l'électricité sur les ménages rwandais, révélant une amélioration de la participation au marché du travail, mais aussi une augmentation des inégalités de revenus, surtout entre hommes et femmes. Le deuxième essai étudie l'autonomisation des femmes et la sécurité alimentaire en Éthiopie, montrant que le contrôle accru des femmes sur les ressources améliore la diversité et l'apport alimentaire des ménages. Le troisième essai s'intéresse aux perceptions économiques des Africains subsahariens, où, malgré des conditions difficiles, un optimisme persiste, lié à la stabilité institutionnelle et à la cohésion sociale. Le quatrième essai explore l'effet des flux d'IDE et des chocs économiques sur l'industrialisation dans 27 pays émergents, soulignant que les IDE encouragent l'industrialisation même en période d'incertitude, tandis que les chocs du PIB n'ont pas d'effet systématique. Le cinquième essai évalue l'impact environnemental des flux d'IDE, où les investissements à long terme améliorent la performance environnementale, tandis que les flux à court terme, notamment en Afrique subsaharienne et au Moyen-Orient, peuvent avoir des effets négatifs. Le sixième essai traite de la convergence environnementale entre pays partenaires d'IDE, montrant que les flux entre pays du Nord tendent vers des normes environnementales plus strictes, tandis que les flux Nord-Sud ou Sud-Sud produisent des résultats hétérogènes. En conclusion, cette thèse souligne l'importance d'institutions et de réglementations environnementales solides pour que les IDE contribuent réellement au développement durable, notamment en Afrique, en explorant comment l'accès aux ressources influence le bien-être et les perspectives économiques.

Mots clés : Investissements Directs Étrangers (IDE), Industrialisation, Convergence Environnementale, Inégalités Sociales, Autonomisation des Femmes, Bien-être des Ménages, Sécurité Alimentaire, Accès à l'énergie, Développement Économique, Durabilité Environnementale, Développement International, Régulations Environnementales, Approche Bilatérale.

Essays on international sustainable development

Abstract :

This thesis addresses issues of international development, focusing on foreign direct investment (FDI), social inequalities, and environmental sustainability. Through six essays, it explores both microeconomic and macroeconomic dynamics using various quantitative methods to examine topics such as women's empowerment, energy access, industrialization, and the environmental effects of FDI. The first essay examines the impact of electricity access on Rwandan households, revealing an improvement in labor market participation but also an increase in income inequalities, especially between men and women. The second essay studies women's empowerment and food security in Ethiopia, showing that increased women's control over resources enhances dietary diversity and household calorie intake. The third essay addresses the economic perceptions of sub-Saharan Africans, where, despite difficult conditions, optimism persists, largely tied to institutional stability and social cohesion. The fourth essay explores the effects of FDI flows and economic shocks on industrialization in 27 emerging countries, highlighting that FDI supports industrialization even in times of uncertainty, whereas GDP shocks do not systematically lead to industrial growth. The fifth essay assesses the environmental impact of FDI flows, finding that long-term investments generally improve environmental performance, while short-term flows, particularly in sub-Saharan Africa and the Middle East, can have negative effects. The sixth essay examines environmental convergence among FDI partner countries, showing that FDI flows between Northern countries tend toward stricter environmental standards, whereas North-South or South-South flows yield more heterogeneous results. In conclusion, this thesis emphasizes the importance of robust institutions and environmental regulations to ensure that FDI effectively contributes to sustainable development, especially in Africa, by exploring how resource access influences well-being and economic prospects.

Keywords : Foreign Direct Investment (FDI), Industrialization, Environmental Convergence, Social Inequality, Women's Empowerment, Household Welfare, Food Security, Energy Access, Economic Development, Environmental Sustainability, International Development, Environmental Regulations, Bilateral Approach.

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*To my family,
particularly my parents and
my brothers Epiphane and Songui.*

Thanks Lord Jesus-Christ!

*The University of Orléans does not intend to give any approval or
disapproval to the opinions expressed in this thesis.
These opinions are to be considered
as the author's own.*

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Abstract

Abstract:

This thesis examines key questions in international development with a focus on foreign direct investment (FDI), industrialization, social inequalities, and environmental sustainability. Through six essays, it analyzes both microeconomic and macroeconomic dynamics using various quantitative methods, addressing topics such as women's empowerment, access to energy, industrialization, environmental convergence, and the differentiated effects of FDI. The ***first essay*** studies the impact of access to electricity on the well-being of Rwandan households. Electrification has led to significant improvements in labor market participation, especially for men, but has also exacerbated income inequalities within households. These results emphasize the need for complementary policy measures to ensure equitable distribution of the benefits of energy access within households, particularly in terms of gender. The ***second essay*** explores the relationship between women's empowerment and food security in rural Ethiopian households. The results show that when women have better control over agricultural resources, household dietary diversity, and caloric intake significantly improve. The study highlights the importance of implementing policies aimed at strengthening women's economic rights to ensure positive effects on food security. The ***third essay*** analyzes the economic perceptions of citizens in sub-Saharan Africa, where, despite often difficult economic conditions, the majority of Africans remain optimistic about the future. This phenomenon of economic optimism is largely influenced by institutional stability, social cohesion, and the quality of public policies. These results highlight the importance of strong institutions to inspire confidence in future economic prospects. The ***fourth essay*** explores the effects of FDI flows and macroeconomic shocks on industrialization in 27 emerging countries. The results show that FDI flows play a key role in promoting industrialization, even during periods of economic uncertainty. However, GDP-related shocks do not systematically lead to industrial growth. The study underscores the necessity of attracting stable, long-term FDI to foster sustainable industrialization in these economies. The ***fifth essay*** examines the differentiated effects of FDI flows and stocks on receiving countries' environmental performance. FDI stocks, representing long-term investments, are generally associated with better environmental performance. In contrast, short-term FDI flows, often driven by immediate economic gains, can lead to negative environmental impacts, particularly in sub-Saharan Africa and the Middle East. The ***sixth essay*** focuses on environmental convergence between countries that are FDI partners. It reveals that FDI flows between Northern countries promote convergence towards stricter environmental standards, whereas FDI flows between the North and South, or between Southern countries, yield more heterogeneous results. This analysis highlights the importance of strengthening environmental regulations to ensure that FDI contributes to sustainable outcomes, particularly in emerging economies. To conclude, ***this thesis*** highlights that FDI can play a crucial role in the sustainable development of developing, emerging, and developed countries, provided that appropriate institutional frameworks and environmental regulations are in place. The thesis also proposes an overall international perspective of different development patterns in African countries (i.e. how access to resources can impact the well-being, namely access to energy or access to agricultural resources), while considering at a broader level how past and current conditions can affect the future economic expectations of the African population.

Keywords:

Foreign Direct Investment (FDI), Industrialization, Environmental Convergence, Social Inequalities, Women's Empowerment, Household Well-being, Food Security, Access to Energy, Economic Development, Environmental Sustainability, International Development, Environmental Regulations, Bilateral Approach.

Résumé

Résumé :

Cette thèse examine des questions centrales en développement international en mettant l'accent sur les investissements directs à l'étranger (IDE), les inégalités sociales et la soutenabilité environnementale. À travers six essais, ce travail analyse des dynamiques à la fois microéconomiques et macroéconomiques, en utilisant diverses méthodes quantitatives, et aborde des thématiques comme l'autonomisation des femmes, l'accès à l'énergie, l'industrialisation, la convergence environnementale, et les effets différenciés d'IDE. Le **premier essai** étudie l'impact de l'accès à l'électricité sur le bien-être des ménages rwandais. L'électrification a permis une amélioration significative de la participation au marché du travail, en particulier pour les hommes, mais a également exacerbé les inégalités de revenu au sein des ménages. Ces résultats soulignent la nécessité de politiques complémentaires pour garantir une répartition équitable des bénéfices de l'accès à l'énergie au sein des ménages, notamment en termes de genre. Le **deuxième essai** explore la relation entre l'autonomisation des femmes et la sécurité alimentaire dans les ménages ruraux éthiopiens. Les résultats montrent que lorsque les femmes exercent un meilleur contrôle sur les ressources agricoles, la diversité alimentaire et l'apport calorique des ménages s'améliorent considérablement. L'étude met en lumière l'importance d'intégrer des politiques visant à renforcer les droits économiques des femmes pour garantir des effets positifs sur la sécurité alimentaire. Le **troisième essai** analyse les perceptions économiques des citoyens en Afrique subsaharienne, où, malgré des conditions économiques souvent difficiles, la majorité des Africains restent optimistes quant à l'avenir. Ce phénomène d'optimisme économique est largement influencé par la stabilité institutionnelle, la cohésion sociale et la qualité des politiques publiques. Ces résultats mettent en évidence l'importance d'institutions solides pour inspirer confiance dans les perspectives économiques futures. Le **quatrième essai** explore les effets des flux d'IDE et des chocs macroéconomiques sur l'industrialisation dans 27 pays émergents. Les résultats montrent que les flux d'IDE jouent un rôle déterminant dans la promotion de l'industrialisation, même en période d'incertitude économique. En revanche, les chocs liés au PIB ne conduisent pas systématiquement à une croissance industrielle. L'étude met en lumière la nécessité d'attirer des IDE stables et à long terme pour favoriser une industrialisation durable dans ces économies. Le **cinquième essai** analyse les effets différenciés des flux et des stocks d'IDE sur la performance environnementale. Les stocks d'IDE, représentant des investissements à long terme, sont généralement associés à une meilleure performance environnementale. En revanche, les flux d'IDE à court terme, souvent motivés par des gains économiques immédiats, peuvent entraîner des impacts environnementaux négatifs, notamment en Afrique subsaharienne et au Moyen-Orient. Le **sixième essai** s'intéresse à la convergence environnementale entre pays partenaires d'IDE. Il révèle que les flux d'IDE entre pays du Nord favorisent une convergence vers des normes environnementales plus strictes, alors que les flux entre pays du Nord et du Sud ou entre pays du Sud produisent des résultats plus hétérogènes. Cette analyse montre qu'il est crucial de renforcer les régulations environnementales pour s'assurer que les IDE contribuent à des résultats durables, en particulier dans les économies émergentes. Pour conclure, **cette thèse** met en évidence que les IDE peuvent jouer un rôle crucial dans le développement durable des pays en développement, émergents et avancés, à condition que des cadres institutionnels et des régulations environnementales adéquats soient mis en place. La thèse propose également une perspective internationale globale des différents modèles de développement dans les pays africains (e.g. en investiguant comment l'accès aux ressources peut impacter le bien-être, notamment l'accès à l'énergie ou aux ressources agricoles), tout en prenant en compte à un niveau plus général comment les conditions passées et actuelles peuvent affecter les attentes économiques futures de la population africaine.

Mots clés :

Investissements Directs Étrangers (IDE), Industrialisation, Convergence Environnementale, In-

égalités Sociales, Autonomisation des Femmes, Bien-être des Ménages, Sécurité Alimentaire, Accès à l'énergie, Développement Économique, Durabilité Environnementale, Développement International, Régulations Environnementales, Bilateral approach.

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General introduction

General Context

A Globalized World Under Pressure

The 21st century has been marked by unprecedented economic, environmental, and social upheavals. Globalization, fueled by technological advances, the rise of international trade, and increased capital mobility, has profoundly reshaped the global economic landscape ([Antràs et Chor, 2022](#); [Gereffi, 2019](#)). At the heart of this transformation are investment flows, particularly Foreign Direct Investment (FDI), which have allowed emerging and developing countries to integrate more deeply into global supply chains and international markets ([World Bank, 2019](#)). For many countries in the Global South, this integration has been seen as a key strategy to accelerate growth, industrialization, and reduce poverty ([UNCTAD, 2021](#)).

However, this rapid and sometimes poorly managed globalization has exacerbated challenges related to inequality, environmental degradation, and unsustainable development ([Ahmed et al., 2022](#)). Some countries have been able to leverage FDI to boost industrialization and economic improvement ([Seyoum, 2024](#); [Dhrifi et al., 2020](#)). However, others have faced growing income inequality, increased vulnerability to global economic shocks, and rising environmental costs ([Bashir, 2022](#)). Simultaneously, climate shocks have intensified, leading to millions of deaths and major socio-economic disruptions, particularly in the most vulnerable regions ([IPCC, 2021](#)). These events highlight the urgency of reassessing development strategies in light of the realities of climate change and its devastating consequences ([World Meteorological Organization, 2021](#)).

In this context, the question of the role of international investments in promoting a more sustainable and inclusive future becomes central ([UNCTAD, 2021](#)). As

climate change causes human and material damage worldwide, disproportionately affecting populations around the world (IPCC, 2021), it is crucial to rethink how FDI can contribute to a transition to more resilient economies (International Energy Agency, 2021). The need to integrate environmental and social imperatives into investment decisions has never been more pressing, as inequalities widen and climate crises lead not only to economic losses but also to human casualties on an alarming scale (Ahmed et al., 2022).

Thus, in an era of climate shocks and global crises, globalization and FDI flows can no longer be evaluated solely through the lens of economic growth. They must now be measured by their ability to contribute to truly sustainable and inclusive development that protects the environment, reduces inequality, and strengthens the resilience of economies (UNCTAD, 2021).

The Urgency of Sustainable Development in a Fragmented World

Sustainable development has become a global imperative, particularly since the adoption of the United Nations Sustainable Development Goals (SDGs) in 2015, which set ambitious targets to eliminate poverty, protect the planet, and ensure prosperity for all by 2030 (United Nations, 2015). Despite notable progress in some areas, the world faces significant challenges, including environmental degradation, rising inequalities, and heightened geopolitical tensions (OECD, 2023, 2022).

In terms of environmental degradation, global carbon emissions have reached alarming levels. Climate change is now considered one of the greatest existential threats to humanity (IPCC, 2021). It is a stark reminder that unsustainable industrial and economic practices have profound repercussions for both the planet and the most vulnerable populations (OECD, 2023).

In terms of social tensions, they have escalated in various regions, where people have expressed dissatisfaction with economic injustice and unequal access to resources and opportunities (Chancel et al., 2022). This social divide, worsened by the pandemic, has undermined global efforts to reduce inequalities.

Regarding geopolitical tensions and economic uncertainties, trade wars, political instability, and global economic volatility, exacerbated by the pandemic, have weakened the foundations of the world economy (International Monetary Fund, 2022).

In this context, sustainable development emerges as a top priority at the world level. More than ever, it is crucial to reconcile economic development with social equity and environmental sustainability ([UN. Department of Economic and Social Affairs, 2022](#)). The challenge is not merely about growing economies but ensuring that their development is socially just and respects the ecological boundaries ([OECD, 2022](#)).

The Role of Foreign Direct Investment in International Sustainable Development

Foreign direct investment has become a key driver of globalization and a crucial tool for development, particularly for countries in the Global South. FDI facilitates the transfer of technology, knowledge, and capital, contributing to industrialization and economic growth. Over the past few decades, regions such as Africa, Latin America, and Southeast Asia have opened their markets to FDI, hoping to leverage its benefits for economic modernization and integration into global value chains.

However, the impact of FDI is not uniform, and its effects vary significantly depending on the economic, social, and regulatory contexts of the host countries. In some cases, FDI has indeed promoted industrialization, increased productivity, and generated employment while supporting the development of essential infrastructure. For instance, investments in renewable energy, sustainable agriculture, and eco-friendly technologies have enabled some countries to make substantial progress toward the Sustainable Development Goals (SDGs), particularly by facilitating the transition to greener and more resilient economies ([Xin et al., 2024](#); [Saqib et al., 2023](#); [Emako et al., 2022](#); [Mahbub et al., 2022](#); [Asongu et Odhiambo, 2020](#); [Saucedo et al., 2020](#)). Positive impacts of FDI include the transfer of clean technologies, infrastructure improvement, and access to global markets, enhancing the capacity of host countries to integrate into global value chains and increase their competitiveness ([Antràs et Chor, 2022](#); [Gereffi, 2019](#); [Hollweg, 2019](#); [Kowalski et al., 2015](#); [Gereffi et Sturgeon, 2013](#)).

Nevertheless, the negative effects of FDI are also significant when not accompanied by appropriate policies and regulations. In countries with weak regulatory frameworks, FDI can exacerbate economic and social inequalities and even encourage unsustainable industrial practices. For example, in certain regions, companies relo-

cate their polluting activities to developing countries where environmental standards are more lax, a phenomenon known as the “pollution haven” hypothesis ([Raihan, 2023](#); [Balsalobre-Lorente et al., 2022](#); [Sarkodie et al., 2019](#); [Acharyya, 2009](#)). The negative impacts of FDI include environmental degradation, increased exploitation of natural resources, and worsening social inequalities, particularly due to the emphasis on rapid economic gains at the expense of long-term sustainable and inclusive development strategies ([Mallick et al., 2020](#); [Han et al., 2023](#); [Hui et al., 2023](#); [Osode et al., 2022](#); [Cheong et al., 2021](#)).

In summary, while FDI represents a significant opportunity for the development of emerging economies, its contribution to sustainable and inclusive development depends on the ability of host countries to implement effective public policies that maximize benefits while minimizing negative externalities.

Development strategies and economic perceptions: a focus on African countries

Over the past decades, development strategies in Africa have focused on economic modernization and integration into global markets to foster sustainable growth and reduce poverty ([African Union Commission et al., 2024, 2023](#); [World Bank, 2022](#)). These strategies, shaped by regional priorities and global economic dynamics, aim to stimulate industrialization, enhance infrastructure, and strengthen human capital, thereby creating a competitive and resilient economic environment. This orientation aligns with the Sustainable Development Goals, which advocate for inclusive progress across economic, social, and environmental dimensions.

A central factor in the effectiveness of these strategies lies in how they are perceived by local populations. Citizens’ economic opinions go beyond mere observations of immediate policy effects; they directly influence trust in long-term development prospects. In economies marked by high volatility, public expectations regarding the economic future significantly impact the confidence climate necessary for implementing policies focused on industrialization, social equity, and sustainability. These perceptions are not only reflections of current conditions but also indicators of social trust in government and institutional actions, acting as a crucial lever for the success of development initiatives.

Moreover, the development experience of African countries vividly illustrates the

complex interplay between national strategies and global economic forces, including foreign direct investment (FDI) flows, trade integration, and technological advances. While integration into global value chains can catalyze growth and encourage innovation, it also exposes local economies to external shocks ([World Bank, 2022](#)). Economic perceptions, by influencing agent confidence, consumption, and investment, thus serve as an indicator of stability and reflect African countries' capacity to manage integration in a resilient manner. Ultimately, understanding the links between development strategies and economic perceptions is essential for supporting sustainable African growth aligned with the goals of equitable and resilient progress.

Our contribution

This thesis, titled *Essays on International Sustainable Development* is built using both a macroeconomic and a microeconomic perspective. The objective is (i) to provide a nuanced understanding of the development strategies employed in African countries with a focus on Rwanda and Ethiopia while explaining and forecasting in general the economic perceptions of the African population; and (ii) to analyze the conditions under which FDI can either support or hinder industrialization and sustainable development goals.

Several key themes are explored throughout the thesis. *First*, a particular focus is placed on key development issues such as household well-being and inequalities. Specifically, the effects of women's empowerment and households' access to electricity on well-being, gender inequalities, and food security are investigated in two African countries (Rwanda and Ethiopia). We show that while access to energy can improve overall household welfare, it can also exacerbate inequalities if not accompanied by appropriate policies. The thesis highlights the need for targeted public policies to ensure that infrastructure investments such as access to electricity lead to more equitable outcomes. Additionally, we extend the analysis to explore, in sub-Saharan countries, the impact of public policies on citizens' perceptions and opinions, analyzing how policies can shape the public's view of economic and environmental progress. *Second*, we investigate how investment, in particular FDI contributes to industrialization, in emerging economies. Our analysis focuses on whether FDI promotes structural economic change and how it interacts with in-

come distribution and regional disparities, raising critical questions about inclusive growth. *Third*, another core topic that we address is how FDI influences environmental policies in host countries. We investigate in particular whether FDI affects the environmental performance of host economies and encourages a convergence towards stricter environmental performance standards or exacerbates environmental disparities, particularly between countries in the Global North and the Global South.

In summary, the thesis addresses the complex trade-offs between industrialization, environmental sustainability, and social equity, emphasizing the importance of well-designed policies to maximize the benefits of access to resources (access to electricity, to agricultural resources or to FDI) while minimizing the potential negative impacts on inequalities and the environment.

Contribution to the Global Debate

The topics examined in this thesis resonate strongly with key global debates, particularly in relation to the Paris Agreement, the Sustainable Development Goals (SDGs), and climate conferences (COPs), all of which advocate for a transition towards more sustainable, inclusive, and environmentally respectful economies.

The findings of this thesis directly contribute to these ongoing global debates: (i) by *exploring the role of women's empowerment in food security*, this thesis offers critical evidence showing that when women have better access to resources and decision-making power, households benefit from improved food security. This contribution is crucial in addressing both gender equality and hunger reduction, supporting global efforts towards achieving sustainable and just food systems; (ii) by *enhancing understanding of the effects of public policies through the perceptions of individuals*. The thesis emphasizes the importance of public trust and effective governance by analyzing how citizens perceive and react to governmental policies, particularly in sub-Saharan Africa. It provides key insights into how policy success can be evaluated not only through economic outcomes but also through the perceptions of citizens; (iii) by *providing empirical insights into the conditions under which investment supports sustainable development*. It explores how foreign investment flows can be effectively leveraged to promote not only industrialization but also environmental and social benefits. It also demonstrates the need for investments that

focus on long-term sustainability, particularly in the context of energy access in rural areas. By analyzing the impact of electrification on household well-being, labor participation, and inequalities, the thesis sheds light on how infrastructure improvements can drive inclusive development; (iv) by highlighting the importance of robust regulatory frameworks for steering FDI towards sustainable development objectives. Rather than focusing solely on economic gains, the thesis stresses the importance of ensuring that investments contribute to long-term environmental sustainability.

Research questions

A central question addressed in this thesis is: under what conditions can investment support sustainable and inclusive economic development while minimizing the negative impacts on the environment, addressing social inequalities, and improving population well-being?

Specifically, several sub-questions can be asked: Do investment-supported infrastructures, such as access to electricity, and public policies, particularly those addressing societal issues and promoting women's empowerment, improve household well-being and reduce intra-household inequalities? Or do these investments exacerbate gender and income inequalities? How do economic policies and outcomes influence people's perceptions of their future? Do FDIs contribute to industrialization? How do FDI flows influence the environmental performance of host countries? Under what conditions do FDIs promote convergence towards environmentally sustainable practices? We seek to answer these questions by analyzing both microeconomic and macroeconomic dynamics using various quantitative methods.

Econometric strategies

The econometric methods used to analyze economic and social impacts across various contexts in our thesis can be summarized as follows. In *Chapter 1*, we employ a **Spatial First Differences (SFD)** method. This is a causal inference technique that leverages spatial data to address unobserved heterogeneity and mitigate endogeneity concerns. By comparing adjacent or neighboring units, SFD minimizes biases stemming from spatially concentrated, unobserved factors that could otherwise confound estimates. This approach is particularly relevant in cases where there is geographic variation in treatment or intervention— such as access to electricity

in our study. By focusing on differences between geographically close units, SFD captures localized effects more precisely and isolates the impact of the treatment variable (electricity access) on the outcomes of interest (household well-being and intra-households inequalities, in our study).

In *Chapters 2 and 3*, **hierarchical regressions**, also known as mixed-effects models, are employed to analyze microeconomic household data or survey data while capturing contextual effects (at the regional or country level). These models are particularly useful for understanding how individual factors (such as women's empowerment in *Chapter 2*) interact with local institutional and infrastructural conditions. This method is also applied in the study of the determinants of African optimism in *Chapter 3*.

In *Chapter 3* we also use **decision trees** to predict future economic perceptions in Sub-Saharan Africa based on macroeconomic and microeconomic (individual-related) variables. This machine learning method identifies the variable combinations with the greatest predictive power. This non-parametric approach is especially useful in determining the factors that influence the economic perceptions of African populations, by combining Afrobarometer survey data with national economic indicators.

In *Chapter 4*, a **PVAR (Panel VAR)** approach is used to analyze the dynamic effects of macroeconomic shocks and FDI flows on industrialization and sustainable development in emerging countries. This method models complex interactions between multiple endogenous variables, accounting for the lagged responses over time. **Network theory** is applied to support the ordering of variable integration in the PVAR, as the sequence in which variables are integrated is crucial.

Standard panel econometric techniques (e.g. **fixed effects panel approaches**) are used in *Chapter 5* to identify the effects of FDI on the environmental performance of host economies. **A bilateral approach, constructed in the spirit of gravity models**, is used in *Chapter 6* to examine the impact of bilateral FDI flows on environmental convergence between the home and host countries. Bilateral analysis captures the specific relationships between each pair of countries, testing whether FDI promotes the harmonization of environmental practices between partners.

Microeconomic and macroeconomic approaches

As previously noted, this thesis employs both microeconomic and macroeconomic data. Concerning **microeconomic data**, we primarily rely on survey data. In Chapter 1, analyzing the effects of electricity on well-being and inequality, we use the Labor Force Survey (LFS), a regular statistical survey conducted (usually by national statistics agencies) to collect detailed information on the labor market. It provides data on employment, unemployment, working conditions, and time use. We also use data from the 2014 survey collected as part of a sustainable intensification program called “Africa Research In Sustainable Intensification for the Next Generation” (Africa RISING), known as the Ethiopia Africa RISING Baseline Evaluation Survey (ARBES). Lastly, we use Afrobarometer surveys, which gather data on citizens’ perceptions of their economic and social conditions. These data help to examine the impacts of public policies on household well-being and understand citizens’ expectations regarding economic growth and future development. Afrobarometer data are particularly useful in analyzing public perceptions of economic and environmental policies in their countries.

As for the **macroeconomic data**, we construct an original bilateral FDI database, drawing from various sources (including author data, official country statistics, and reliable international or non-governmental organizations). Further, we complement our data with macroeconomic data from several sources, including the World Bank (World Development Indicators), the bilateral FDI database, and the Penn World Table. These data cover a wide range of economic, environmental, and institutional indicators, such as GDP, FDI flows and stocks, energy consumption, and trade policies. These datasets are very useful for national and international analyses aimed at examining the impact of FDI on industrialization and environmental performance/convergence.

Thesis Structure

The structure of this thesis is designed to provide a logical and coherent progression, starting with the analysis of the microeconomic impacts of investments and infrastructure on households, and expanding to the macroeconomic effects of a specific type of investment, FDI, on industrialization and environmental sustainability.

Each chapter addresses a key aspect of economic development, focusing on inequalities, industrial dynamics, and environmental performance. Our research goes from a micro to macroeconomic approach, while linking themes through cross-cutting questions such as inequality, convergence, and sustainability.

The first chapters (Chapters 1 and 2) focus primarily on the microeconomic impacts of investment and policies, at the household level, highlighting internal inequalities and well-being dynamics in two African countries (Rwanda and Ethiopia). These chapters also introduce gender issues and access to infrastructure, which are essential elements for understanding development at the local level. Chapter 3 serves as a transition from the microeconomic scale of households to the macroeconomic scale of economic perspectives and investigates Sub-Saharan countries as a whole, within an international comparative framework. The subsequent chapters (Chapters 4 to 6) shift to a more macroeconomic scale, addressing themes such as industrialization, macroeconomic shocks, and environmental sustainability in an international framework. This part of the thesis highlights how FDI influences national and regional economies, in terms of both economic growth and environmental performance.

The structure of this thesis is thus organized progressively, beginning with an analysis of the localized effects of economic policies and investments on household dynamics within African countries, and extending to examine the broader international impacts of investments on the industrialization and sustainability of economies around the world.

Chapter 1: Electricity, welfare, time allocation and inequalities within households: Evidence from Rwanda

This chapter explores the effect of access to electricity on the well-being of rural households in Rwanda. The main objective is to understand how electrification affects the allocation of work time, income inequalities within households, and labor market participation, with a particular focus on gender and age differences. The study relies on microeconomic data from Rwanda's Labor Force Survey (2018), employing a robust econometric method (Spatial First Difference) to address issues of endogeneity.

The results indicate that access to electricity generally improves household well-being, particularly by increasing men's participation in the labor market and enhancing domestic productivity. However, the study highlights that electrification tends to exacerbate gender inequalities: men benefit more from the economic gains, while women often remain marginalized due to traditional household roles. Additionally, younger individuals and women benefit less from these gains, especially in terms of educational outcomes and economic participation.

In conclusion, the study recommends strengthening public policies to accompany electrification with measures aimed at reducing intra-household inequalities, particularly for women. Specific initiatives, such as training programs and economic inclusion measures for women, are essential to maximize the positive effects of access to electricity and ensure more equitable development.

Chapter 2: Women's Empowerment in Agriculture and Household Food Security: Evidence from Rural Ethiopia

This chapter examines the role of women's empowerment in agriculture on the food security of rural households in Ethiopia. Using microeconomic data and quantitative methods such as regressions and classification techniques, the study analyzes how women's access to productive resources (such as land and livestock) and their participation in decision-making influence household dietary diversity and caloric intake.

The results demonstrate that women's empowerment has a significant positive impact on household food security. When women have greater control over productive resources and actively participate in agricultural decision-making, households show higher dietary diversity and increased caloric consumption. The study also highlights that empowering women helps reduce concerns about food shortages, contributing to long-term food stability.

This chapter underscores the importance of implementing public policies aimed at improving women's access to agricultural resources and strengthening their role in economic decisions. These measures are crucial for combating malnutrition and ensuring better food security in rural households. In conclusion, the study advocates for agricultural reforms and training programs aimed at empowering women and

maximizing their contribution to sustainable rural development.

Chapter 3: Determinants and Forecasts of Economic Perceptions in Sub-Saharan Africa: A Macro and Microeconomic Approach

This chapter analyzes African citizens' perceptions and forecasts their opinions concerning future economic conditions in sub-Saharan Africa. Using a combination of microeconomic data from Afrobarometer surveys and macroeconomic variables from multiple databases (36 countries covering 2011 to 2018), the study explores the factors that influence the economic optimism of African populations, often despite challenging economic conditions.

The findings reveal that, despite difficult past and present economic conditions, the majority of Africans remain optimistic about the future. This optimism is primarily driven by political stability, social cohesion, and trust in institutions. The chapter also shows that individuals are more optimistic in countries where public institutions are considered strong and where government policies are perceived as effective. Additionally, levels of optimism are influenced by factors such as macroeconomic stability, security, and the reduction of social inequalities.

This chapter underscores the importance of institutions and public policies in promoting an environment conducive to economic optimism. It demonstrates that improving future economic conditions depends not only on current economic performance but also on the perception populations have of government policies and institutional actions. In conclusion, the study recommends strengthening public institutions, investing in social cohesion, and maintaining political stability to improve economic outlooks in sub-Saharan Africa.

Chapter 4: Shocks and industrialization in emerging countries: a PVAR approach

This chapter examines the impact of macroeconomic shocks, both internal and external, on the industrialization process in emerging countries. Utilizing a Panel Vector Autoregressive (PVAR) model and bootstrap methods to address endogeneity issues, the study draws on data from 27 emerging countries between 1980 and 2019.

The findings show that foreign direct investment (FDI) inflows play a positive and sustained role in the industrialization of emerging economies, while GDP growth alone does not guarantee increased industrial output. Global shifts—like crises, trade liberalization, and evolving supply chains—impact these economies, yet only FDI emerges as a reliable determinant of industrial growth. In contrast, shocks from trade openness and capital liberalization lack a direct impact, underscoring the importance of public policies that prioritize FDI to foster industrial development.

The chapter highlights the importance of prudent macroeconomic management and proactive public policies to stabilize the economy and mitigate the negative impacts of external shocks. In conclusion, it emphasizes that public policies aimed at attracting and stabilizing FDI, while protecting industrial sectors from external shocks, are crucial for ensuring sustained and durable industrialization in emerging economies.

Chapter 5: Impact of FDI on Environmental Performance in Host Countries

This chapter analyzes the effect of foreign direct investment (FDI) inflows and stocks on the environmental performance of host countries between 2001 and 2021. Drawing on bilateral data covering 174 countries and employing robust econometric methods, the study differentiates between the short-term effects of FDI inflows and the long-term effects of FDI stocks on various environmental performance, including CO2 emissions and natural resource management.

The results show that FDI inflows, often associated with rapid economic gains, can have negative impacts on environmental performance, particularly in developing countries where environmental regulations tend to be weaker. On the other hand, FDI stocks, translating a longer-term perspective of investments, are generally correlated with improved environmental performance. This distinction is especially important in regions such as Sub-Saharan Africa and the Middle East, where FDI stocks from developed countries tend to have a more positive impact, while FDI inflows may exacerbate environmental degradation.

In conclusion, the chapter recommends public policies that prioritize FDI while strengthening environmental regulations to mitigate the negative impacts of short-

run inflows. It also emphasizes the need for international collaborations to ensure that FDI contributes to sustainable economic growth while aligning with environmental goals.

Chapter 6: How bilateral FDI influences environmental convergence

This chapter focuses on the bilateral interactions between countries regarding foreign direct investment (FDI) flows and their impact on environmental convergence. The objective is to understand whether and how FDI flows between partner countries promote the harmonization of environmental policies, particularly between sending and receiving countries.

The study's findings show that bilateral FDI from developed countries (North-North) tends to improve the environmental performance of host countries, fostering convergence toward more environmentally friendly practices. In contrast, FDI flows between the North and South or among developing countries (South-South) do not always lead to positive convergence. In some cases, these investments may even exacerbate environmental challenges in developing countries, largely due to weaker local environmental regulations.

This chapter highlights the importance of establishing robust environmental regulations in FDI-receiving countries to maximize the benefits of these investments. It also advocates for stricter bilateral collaborations, with environmental clauses in FDI agreements, to ensure that investment flows contribute to positive environmental convergence. In conclusion, the chapter suggests that while developing countries seek to attract FDI, they must ensure that these flows support sustainable growth and environmentally responsible practices.

1

Electricity, welfare, time allocation and inequalities within households: Evidence from Rwanda¹

Abstract: This study explores the microeconomic impact of electricity access on household welfare, particularly through time allocation within the household. It also investigates how electricity affects intra-household time and income inequality, labor market participation, and school performance, with a focus on gender and age differences. We develop a time allocation model where electricity access is treated as a technological shock that reallocates time across work, domestic activities, and leisure. A Spatial First Difference (SFD) method is employed to estimate causal effects, addressing bias from unobservable factors. Using data from the 2018 Rwanda Labor Force Survey, the results show that access to electricity improves household welfare, especially in households led by men. Older adults (above 35) and young children benefit the most, but the effects on younger adults (18-35) and teenagers (13-17) are limited, particularly in terms of school performance. While electricity reduces the burden of domestic work, it leads to income inequality within households, primarily between the head of the household and the spouse, due to unequal gains in working time. Moreover, access to electricity is strongly associated with increased male labor market participation, while the effect on women is small. For children, access to electricity is associated with reduced labor market participation, which may reflect improved household living conditions by reducing the need for child labor.

Keywords: Access to electricity, Spatial First Difference, Time allocation, Welfare, Inequality

JEL Codes: C31, D63, I31, L94, O15, O18, R29

¹This chapter is co-written with Ahmed Tritah (University of Poitiers). A short paper based on this study has been published in *Revue d'économie du développement*. See Ahouangbe, L. V., Tritah, A. (2022). Access to electricity and children well-being: New evidence from Rwanda 1. *Revue d'économie du développement*, 31(2), 43-49. URL: <https://doi.org/10.3917/edd.362.0043>

*« Durant mon enfance... je devrais avoir entre 5 et 7 ans... j'aidais
ma mère dans son commerce avec mon frère, Rovi, et ma sœur,
Aboutchou.*

*Il fallait être debout avant le lever du soleil pour l'aider avec les tâches
ménagères : elle était vendeuse de bouillie et de gâteaux. Elle devait
donc chaque matin préparer ces plats pour qu'ils soient prêts au lever
du jour. Le seul « hic » était que nous n'avions pas accès à
l'électricité. L'une de mes tâches était de surveiller la bougie afin
qu'elle ne s'éteigne pas ; je devais la protéger du vent.*

C'était mon quotidien d'écolier.

*Ce n'est que quelques années plus tard qu'arriva l'aubaine pour mon
quartier : nous avons enfin eu accès à cette « très fameuse » électricité
! Ma mère me réveillait désormais beaucoup plus tard le matin. En
fait, je profitais chaque jour d'un peu plus de temps de sommeil.
Plusieurs de mes activités ont été éliminées, principalement la
surveillance des bougies qui ont été remplacées par des lampes à
incandescence.*

C'était bien mieux!

*Les économistes diront probablement que mon « **bien-être** » a été
amélioré, un terme dont j'ignorais alors l'existence. Du haut de mes 8
ans, j'étais juste content de profiter d'un temps de sommeil
relativement plus long. C'est pour avoir vécu cette transition, pour
avoir ressenti ce confort nouveau et avoir intimement compris ce qu'il
m'apportait en qualité de vie quotidienne que je m'intéresse
aujourd'hui à ce sujet.*

*Puisse cette étude sur la population rwandaise nous permettre de bien
comprendre les différents impacts de l'électrification des ménages pour
une société. »*

- Vignawou Lucien AHOUE (Eli) -

“During my childhood... I should be between 5 and 7 years old... I helped my mother in her business with my brother, Rovi, and my sister,

Aboutchou.

I had to be up before sunrise to help her with the household chores: she sold porridge and cakes. She had to prepare these dishes every morning so that they would be ready at sunrise. The only “problem” was that we didn’t have access to electricity. One of my tasks was to watch the candle so that it would not go out; I had to protect it from the wind.

That was my daily routine as a schoolboy.

It was only a few years later that a godsend arrived for my neighborhood: we finally had access to this “very famous” electricity! My mother used to wake me up much later in the morning. In fact, I was getting a little more sleep every day. Many of my activities were eliminated, mainly watching the candles which were replaced by incandescent lights.

It was much better!

*Economists would probably say that my “**well-being**” was improved, a term I didn’t know existed at the time. At the age of 8, I was just happy to enjoy a relatively longer sleep time. It is because I lived through this transition, felt this new comfort and intimately understood what it brought me in terms of daily quality of life that I am now interested in this subject.*

May this study on the Rwandan population allow us to fully understand the different impacts of household electrification for a society.”

- Vignawou Lucien AHOUANGBE (Eli) -

1.1 Introduction

Electrification is widely recognized as a critical driver of economic growth and poverty reduction. However, millions of people in developing countries (DCs) still lack access to reliable electricity, despite its well-documented benefits at the macroeconomic, mesoeconomic, and microeconomic levels (Dinkelman, 2011; Khandker et al., 2013; Bridge et al., 2016). At the macro level, electrification fuels industrial development, enhances productivity, and attracts investments. At the meso level, it fosters regional development by improving infrastructure and public services. At the micro level, it improves household welfare by generating new employment opportunities, enabling the creation of new businesses, and enhancing productivity within small enterprises (Kalt et al., 2019; Pueyo and Maestre, 2019; Pelz and Urpelainen, 2020).

For households, the immediate benefits of electricity access are tangible. Once connected to the grid, households gain access to more leisure activities and facilities for the day-to-day life. Additionally, family-run businesses can extend their operational hours, enhancing productivity and increasing income (Khandker et al., 2013). These improvements translate into direct gains in quality of life, increased time for paid work, and reduced workloads at home.

Given these advantages, electrification has been deemed essential to achieving the United Nations Millennium Development Goals (MDGs), particularly in combating poverty and fostering human development (Ogola et al., 2011; Khandker et al., 2013; Shyu, 2014; Alam et al., 2018). Yet, despite progress, a significant portion of the population in developing countries remains without access to electricity. According to Shyu (2014), in 2009, over 1.3 billion people, predominantly in developing countries, lacked access to electricity, with 84% of them living in rural areas. Furthermore, despite the major efforts being made worldwide, IEA (2020) points out that by 2020, 80% of the people in the world without access to electricity will live in rural areas, including three out of four in sub-Saharan Africa.

Efforts to address this gap have intensified since the adoption of the Sustainable Development Goals (SDGs), which replaced the MDGs in 2015. Many developing countries have made electrification a cornerstone of their national development strategies. For example, Rwanda has made significant strides in expanding

household electrification as part of its National Strategy for Transformation (NST1), aligned with both the SDGs and the country’s Vision 2020 and Vision 2050 frameworks.

The economic impacts of electrification programs are a key focus of both national governments and international development institutions. Numerous studies have examined the effects of electricity access on macroeconomic indicators, as well as household-level outcomes such as employment, health, education, and consumption (Dinkelman, 2011; Grogan and Sadanand, 2013; Dasso and Fernandez, 2015; Khandker et al., 2013; Barkat et al., 2002; Van de Walle et al., 2013; Bridge et al., 2016; Rathi and Vermaak, 2018). Overall, the evidence suggests that electricity access has significant positive effects on socio-economic well-being, with varying impacts based on gender (Pueyo and Maestre, 2019).

However, relatively few studies have explored the intra-household effects of electrification. Some, such as Grogan and Sadanand (2013) and Barron and Torero (2014), have investigated the impact of electricity access on time allocation and individual well-being. While these studies suggest a positive correlation, they are limited in scope, focusing on specific activities or individuals rather than entire households. This raises the the following questions: Does access to electricity affect household and individual well-being through time allocation? Additionally, could access to electricity be a source of intra-household inequality; i.e. does it exacerbate or reduce it?

Our study aims to address these gaps in the literature by providing answers to these questions: (a) How does access to electricity affect both household and individual well-being through time allocation? (b) Does access to electricity exacerbate or reduce intra-household inequality? Our analysis builds on previous work by Grogan and Sadanand (2013) and Barron and Torero (2014), extending their findings to examine the effects of electricity on time allocation and household well-being, as well as the distribution of income and labor force participation within households.

To our knowledge, this study is the first to analyze the impact of electrification on all three dimensions of time allocation—market time (labor market participation), non-market time (domestic work), and leisure time—while also examining intra-household inequalities in time and income. Furthermore, we estimate the causal

effects of electricity access at spatial level taking account of the spatial distribution of the data, offering a more comprehensive understanding of its socio-economic impacts.

Building on the model of time allocation proposed by [Gronau \(1977\)](#), we introduce access to electricity as a technology shock, leading to a reallocation of time across different activities (market work, domestic work, and leisure). We hypothesize that access to electricity improves the well-being of children by reducing their involvement in household labor, increasing their leisure time, and improving school performance. For adults, particularly household heads, electricity access is expected to increase labor market participation, reduce domestic work, and enhance leisure time, leading to higher income and improved well-being.

We use the Spatial First Difference (SFD) method to test empirically the effects of electrification on household well-being. The method, developed by [Druckenmiller and Hsiang \(2018\)](#), allows to address issues of unobserved heterogeneity and potential endogeneity in the estimation of causal effects. This approach mitigates biases caused by unobservable variables and spatial concentration, providing robust causal estimates of electrification's impact on household well-being.

Our empirical analysis is based on Rwanda's 2018 labor force surveys. These surveys are highly suitable for the SFD method due to the spatial concentration of households and the high-quality data available. The results indicate that access to electricity significantly improves household well-being, with the strongest effects observed among households headed by men. However, the benefits of electrification vary across age and gender, with older adults and young children experiencing the most substantial improvements, while younger adults and teenagers see fewer gains.

The remainder of this chapter is organized as follows: Section [1.2](#) reviews the literature on the microeconomic effects of electrification. Section [1.3](#) presents the theoretical framework of the study, and Section [1.4](#) outlines the theoretical assumptions. Section [1.5](#) describes the data sources, while Section [1.6](#) explains the methodology. Section [1.7](#) links the descriptive analysis to the theoretical hypotheses, and Section [1.8](#) discusses the empirical results. Finally, Section [1.9](#) offers concluding remarks.

1.2 Literature review

In this section, we review how access to energy—specifically electricity—affects the well-being of both connected and unconnected individuals, directly or indirectly. The literature consistently portrays access to electricity as a technological shock (Costa et al., 2009; Grogan and Sadanand, 2013; Salmon and Tanguy, 2016). This shock results in significant changes in household endowments, such as the acquisition of appliances like refrigerators, electric cookers, lighting, televisions, and radios (Khandker et al., 2013). Additionally, it positively affects household time allocation by reducing the time spent on manual tasks and increasing opportunities for productive activities (Barron and Torero, 2014; Costa et al., 2009). These changes yield several outcomes, including improved food preservation, more efficient cooking, greater access to information, enhanced study conditions for children, and the development of income-generating activities, ultimately improving productivity in both market and non-market household activities (Independent Evaluation Group, 2008).

The main benefits of these transformations can be observed in several dimensions: (a) income, driven by the productive use of electricity, longer working hours, and better employment opportunities; (b) education, through increased study time and improved school performance (Barkat et al., 2002); and (c) health, due to improved air quality and reduced use of polluting fuels for lighting (Khandker et al., 2013). Furthermore, access to electricity is associated with improved consumption patterns and higher household expenditures, driven by increased income and reduced reliance on candles or other pollutants for lighting. For instance, Röllin et al. (2004) find that electrified rural households in South Africa have significantly lower levels of indoor air pollution compared to non-electrified households. Even unconnected households can benefit indirectly from electricity through community street lighting, which enhances security and contributes to overall well-being (Khandker et al., 2013).

However, access to electricity does not impact all household members equally. Differences in electricity use and the distinct roles of household members—whether heads of households, spouses, children, or adults—result in varying impacts on time allocation and productivity. For instance, Costa et al. (2009) highlights that time allocation is significantly influenced by gender, with distinct work opportunities for

men and women ([Pueyo and Maestre, 2019](#)). Moreover, the title of “household head,” typically associated with greater responsibility for household income, further differentiates time use between spouses and other household members.

Despite these well-established benefits, the literature remains inconclusive regarding the full impact of electricity on well-being. Policymakers often emphasize these welfare improvements as justifications for electrification investments, yet empirical evidence shows mixed results.

A significant body of literature focuses on the link between electrification and income, particularly through employment development. [Dasso and Fernandez \(2015\)](#) assess the impact of an electrification program in Peru, demonstrating that men experience an increase in working hours and a reduced likelihood of holding multiple jobs. For women, electrification correlates with higher employment rates and income, particularly in non-agricultural sectors. However, a gender wage gap persists among program beneficiaries. In South Africa, [Dinkelman \(2011\)](#) find that female employment increases significantly post-electrification, while male employment remains largely unchanged. Electrification enables women to reduce time spent on household production, freeing them to engage in income-generating activities. Similarly, [Grogan and Sadanand \(2013\)](#) finds that rural electrification in Nicaragua significantly alters time use, especially for women, who are more likely post-electrification to work outside the home.

Nevertheless, other studies provide contrasting evidence, particularly concerning women’s labor. [Salmon and Tanguy \(2016\)](#) argue that intra-household dynamics can lead to unequal benefits, with electrification primarily increasing men’s work time at the expense of women’s. In rural Ghana, [Costa et al. \(2009\)](#) find that electricity does not affect the domestic work time of women but increases the hours spent on market activities, without affecting their overall labor market participation.

The literature on the effects of electricity on education, health, and productivity has expanded in recent decades. For example, [Bridge et al. \(2016\)](#) examine electrification in Nepal and find significant positive effects on income, education, and agricultural productivity. Similarly, [Khandker et al. \(2013\)](#) show that rural electrification in Vietnam enhances children’s school attendance, with girls benefiting more than boys.

While electrification clearly affects various dimensions of well-being, its impact on time allocation—particularly across market work, non-market work, and leisure—is limited. Early theories of time allocation, such as those by [Becker \(1965\)](#) and [Gronau \(1977\)](#), provide frameworks for analyzing how individuals allocate time across these three dimensions. However, much of the existing literature focuses on market or non-market work, neglecting leisure time ([Dinkelman, 2011](#); [Grogan and Sadanand, 2013](#); [Khandker et al., 2013](#); [Van de Walle et al., 2013](#); [Bridge et al., 2016](#); [Salmon and Tanguy, 2016](#); [Rathi and Vermaak, 2018](#)).

Only a few studies have attempted to analyze all three dimensions of time allocation simultaneously. For example, [Barron and Torero \(2014\)](#) study the effects of electricity on household behavior in El Salvador and find that electrification increases children’s educational attainment and women’s participation in non-farm activities, though its effects on leisure and male employment are limited. [Grogan and Sadanand \(2013\)](#) apply the time allocation model of [Gronau \(1977\)](#) to rural Nicaragua and find that electrification significantly reduces women’s time spent on agricultural activities but has little effect on cooking or domestic work.

In summary, while the evidence points to significant gains from electrification in terms of income, education, and productivity, further research is needed to fully understand how electricity impacts time allocation and intra-household inequality. The following section presents our theoretical model.

1.3 Theoretical framework

In this section, we present the theoretical model in which our study is embedded, and develop an analysis of the introduction of technology shocks in the model. First, we present the basic model, then we introduce electricity as a technology shock, and finally, the costs associated with electrification.

1.3.1 Theoretical Model

The theoretical framework of this study is based on the [Gronau \(1977\)](#). This model proposes a framework for analyzing the optimal allocation of time between domestic, market and leisure activities. In its basic conception, we assume a one-person household that seeks to maximize its utility U , which depends on the combination

of goods - and services - (X) and consumption time (L , leisure) defined by²:

$$U = U(X, L) \quad (1.1)$$

It is composed of the consumption of goods - and services - acquired on the market (X_m) or those produced domestically (X_d), such that $X = X_m + X_d$. The domestic production of goods depends on the domestic working time (D), such that $X_d = f(D)$. It is assumed that this home production function $f(D)$ is subject to decreasing marginal productivity. It is also assumed that there is no joint production, i.e. that an input is not used jointly for the production of domestic and market goods.

Maximizing U is subject to two constraints. Goods acquired from the market are subject to the following budget constraint:

$$X_m = wN + V, \quad (1.2)$$

Where, w is the wage rate (assumed to be constant), N is the time spent working in the market, and V represents all other sources of income. The time constraint is given by

$$L + D + N = T. \quad (1.3)$$

Maximizing U under constraints leads to the optimum at:

$$\frac{\frac{\partial U}{\partial L}}{\frac{\partial U}{\partial X}} = f' = w^* = w \quad (1.4)$$

At the optimum, we obtain the opportunity cost of time, or the implicit price of time (w^*). This relation expresses the equality between domestic marginal productivity and the rate of substitution between goods and leisure. At a given wage rate (w), we can determine, via the rate of substitution, the optimal working time (domestic and market) and leisure time. Equality at domestic marginal productivity allows us to obtain the optimal allocation of time between market and non-market work.

²Hence, in the rest of the theoretical framework, we will use household and individual interchangeably.

The different possible cases of optimal time allocation are shown in Figure 1.A1 (solid lines). The home production function is represented by the TAG_D curve. In the absence of opportunity in the labor market, this curve represents the frontier of production possibilities, and thus the set of combinations between (domestic) work and leisure. The labor market, offering the opportunity to earn a real wage w by reallocating one's domestic labor time into time spent in the labor market, in order to purchase market goods, is represented by the line AG_M (slope representing the real wage w) tangent to the TAG_D curve at point A .

In Figure 1.A1a, we represent the behavior of an economic agent (at the optimal point B) with strong preferences for leisure. A highly leisure intensive consumption technology is to be noted. The economics agent divides his time into leisure time (L) and home production time (D) for a quantity of home goods (X_d). On the other hand, point B in Figure 1.A1b represents the optimum for an economic agent with a goods-intensive technology (having more preference for goods). He divides his time into leisure time (L), market work time (N) leading to the acquisition of market goods (X_m), and domestic work time (D) for the production of domestic goods (X_d).

1.3.2 Introduction of a technological shock: Electricity

Based on the properties of this simple model, Gronau (1977) analyzes the implications of an increase in other sources of income, an increase in the wage rate and the introduction of entry costs into the labor market.

In our study, we seek to analyze the implications that may arise from a positive technological shock, namely, access to electricity, leading to an increase in total time endowment. For example, rural households in developing countries often rely on traditional means for the production of goods. Most of these traditional means incur significant time costs; for example, the time taken to fetch wood from the forest before cooking with fire. Access to electrical energy can lead to increased productivity and time savings. Indeed, households will save time by turning away from traditional means to more modern ones (for example, cooking by firewood, which involves a time cost due to the search for wood in the forest, can be replaced by faster electric cooking means). They will allocate this saved time to the production of goods (market or non-market) or to their leisure. It can also be noted that goods

intensive in electrical energy will increase in terms of production or use. Additionally, in these poor families, lack of light or lighting affects children's performance at school. In particular, poor lighting can lead to poor performance in school, resulting in low levels of human capital. Electricity can increase the amount of time children spend studying, with lighting at night.

Grogan and Sadanand (2013) state that “*When a household has no possibility of choosing electricity, effective hours available for home production are constrained by daylight. If electric light becomes available, potential hours of activity are expanded dramatically. For example, women who received solar, off-grid electricity in Estelí, a municipality of Nicaragua, confirmed that this light extends their day. Comments included in a subjective case study of the project included “Its easier to live this way. My kids can read and do homework during the night.” and “Solar energy is forever. We leave our lights on and sit around the table and talk. This is happiness.”...*”.

Thus, access to electricity leads to productivity gains (primarily via the use of electrical appliances), changes in time allocation (productive and non-productive), improvements in human capital, and overall improvements in household well-being. But the purpose of this study is not to analyze the effects on productivity, even if it does affect output.

From a theoretical point of view, the time savings due to access to energy result in a change in the time constraint. The total endowment in the new constraint is T' , such that $T' \geq T$. The maximization program becomes:

$$\left\{ \begin{array}{ll} \max(U) : & U = U(X, L) \\ \text{where} & X = X_m + X_d \text{ and } X_d = f(D), \\ \text{s.c.} & X_m = wN + V, \\ & L + D + N + \gamma t = T'. \end{array} \right. \quad (1.5)$$

such as $\gamma = 1$, if the individual has access to electricity, then $T' \geq T$; and $\gamma = 0$, otherwise, then $T' = T$. γt represents the one-time shock that the household will have to allocate over home production time, market work time, and leisure time.

The different possible cases of optimal time allocation with the introduction of the positive time endowment shock due to access to electricity (technology shock) are shown in Figure 1.A1 (in dashed lines) in the appendix. The new household pro-

duction function is represented by the curve $T'A'G'_D$. In the absence of opportunity in the labor market, this curve represents the production possibilities function, and thus the set of combinations between (domestic) work and leisure. Indeed, it offers a higher production set than TAG_D . An individual who devotes all the time (T') to home production will produce at a level equal to OG'_D , higher than the initial level OG_D with a time allocation T . The existence of the labor market, offering the opportunity to earn a real wage w by substituting one's time in home production for work paid for in the market in order to purchase market goods, is represented by the line $A'G'_M$ (slope representing the real wage w) tangent to the curve $T'A'G'_D$ at point A' . This line has the same slope as initially, because the wage rate (assumed constant) has remained unchanged.

In Figure 1.A1a in the appendix, the individual with strong preferences for leisure (a highly leisure-intensive consumption technology) moves from point B to point B' after the shock. This economics agent will divide his time into leisure time (L') and home production time (D') for a given quantity of home goods (X'_d). Following the availability of additional time, this individual will increase his leisure time ($L' \geq L$) and his home production time ($D' \geq D$). This results in an increase in the goods produced at home ($X'_d \geq X_d$).

On the other hand, in Figure 1.A1b, the individual with a goods-intensive technology (having more preference for goods) initially at point B finds himself after the shock at point B' . He divides his new time allocation (T') into leisure time (L'), market work time (N') leading to the acquisition of market goods (X'_m) and domestic work time (D') for the production of domestic goods (X'_d). In this case, when we compare the new distribution of time and production levels with the initial situation, we notice an increase in leisure time ($L' \geq L$) and an increase in domestic work time ($D' \geq D$). The latter leads to an increase in domestic goods produced ($X'_d \geq X_d$). But as regards time (N') and production (X'_m) of market goods, their variations remain uncertain if we rely on some of the assumptions of the model, notably the constant wage rate w and the marginal domestic productivity f' . With the wage rate unchanged, the individual does not conceive of a variation in the relative price between home-produced goods and market goods. Moreover, marginal productivity is not affected (theoretical assumption), i.e. the home production curve has

not changed shape but it changes location, shifting upwards to the right. It would be difficult to conclude that labor time in the labor market has increased from its initial level, so N' will be equal to N . This being the case, the level of production of market goods also remains unchanged, so $X'm = Xm$.

However, in reality, this productivity shock would affect the shape of the home production function, so it is very likely that the change in productivity would affect the time spent in the market (through a decrease in the time spent in the market for an individual whose consumption technology is strong in home goods or leisure, through an increase in the time spent in the market for an individual whose consumption technology is strong in market goods). This change would occur following a change in the individual's productivity due, for example, to the intensive use of electrical appliances. In order to have a relatively simple theoretical framework, we do not include this change in this paper. This remains for further analysis.

1.3.3 Introduction of cost

It should be noted that there are multiple costs of access to electricity.

Access to electricity is subject to a set of non-zero costs that must be incorporated into the model. These costs include: consumption costs per kilowatt hour, contract costs related to the signing of the electricity contract, and connection costs. The latter can be significant because they are related to the geographical and topological position of the house, the cost of connection of an isolated house located in altitude will be much higher than for a house located in urban area already electrified. Thus, all of these network access costs can constitute a barrier to entry; because of these market entry costs, some households with adequate incomes to afford electricity will still forego electrification of their homes.

We characterize these different costs as C . The introduction of these costs changes the budgetary and time constraints to:

$$X_m + \gamma C = wN + V, \quad (1.6)$$

$$L + D + N + \gamma t = T'. \quad (1.7)$$

Let's remember that if the individual has access to electricity $\gamma = 1$, then $T' \geq T$,

otherwise, $\gamma = 0$ then $T' = T$. γt represents the additional time shock the household will have to allocate as already mentioned.

Figure 1.A2 shows the implications one can have of access to electricity on time allocation with the introduction of costs. Figure 1.A2a shows the optimal time allocation of an individual with a leisure intensive production technology; and in Figure 1.A2b, the time allocation of a goods intensive individual. The lines or curves in black solid lines characterize a situation without electricity ($\gamma = 0$). Those in gray solid lines show an illustrative phase of the impact of electricity access costs on the time distribution ($C \neq 0$). Those with black dashed lines represent the final situation showing time distributions (T') taking into account electricity access costs ($\gamma = 1$, and $C \neq 0$) and the effects of electricity on the time distribution.

On the one hand, for a leisure-intensive individual (Figure 1.A2a), access to electricity leads to a shift of the home production function TAG_D to the right, $T'A'G'_D$; and the optimum initially at point B is now at point B' for a rational individual (i.e., one who efficiently allocates the extra endowment so as to always maximize her utility function). We notice that for such an individual, leisure time and home production time increase ($L' \geq L$ and $D' \geq D$). This also implies an increase in home production, from X_d to X'_d . However, for an irrational individual, who would not allocate the extra time induced by electricity, the equilibrium would be at B^* . In this case, the individual pays the costs of access to electricity, with an equivalent deducted from the home production ($X_d - X_d^* = C$) and the initial time allocation T remains unchanged. At the end, the individual ends up with a lower home production ($X_d^* < X_d$) and an unchanged initial time allocation.

On the other hand, for a goods-intensive individual (Figure 1.A2b), access to electricity also leads to a new equilibrium at the optimum, point B' , with a better production function than initially ($T'A'B'G'_M$ at top right of $TABG_M$). We note an increase in leisure time ($L' \geq L$) and in domestic work time ($D' \geq D$), but it is difficult to know the impact on work time (as before). The analysis is more complex for domestic work time or the labor market, and their variations will depend on the nature of the market and the motivation of the individual. If we stick to the assumptions of the model and assume that the market is rigid, it is therefore difficult to increase working time in the market if wage rates are fixed; it is only domestic

time that would increase. But in a flexible market where working time can be easily increased, both (domestic and market work) time would increase. For individuals with a very labor-intensive production technology, labor market time would increase and home production time is expected vary only slightly.

1.4 Theoretical assumptions of the model and welfare

1.4.1 Theoretical assumptions of the model

In this part, we advance the theoretical assumptions of our study by linking them to the specific context of developing countries and to the literature on the effects of electricity. Let's remember that the effects of electricity differ according to gender and the individual's role in the household (head of household, child, wife, etc.). Table 1.B1 summarizes the expected signs of the effects of electricity on time allocation.

Children We assume that access to electricity will reduce the time spent working in the market and the time spent on domestic work. However, the effect on domestic work time may be small or non-existent, due to the increase in domestic chores (e.g., maintaining electrical appliances) that may be diverted to children if parents spend more time in the labor market to support the increasing needs for electricity (e.g., consumption and expenses, electricity fees). Furthermore, electricity is expected to increase leisure time. We are also interested in the effects on children's education. Electrification may improve the returns to children's education and encourage them to attend school by enabling longer study hours with night-time lighting. In other words, electricity will positively impact children's education and thus enhance human capital.

Household Heads We assume that due to increasing household burdens, heads of household will spend more time working in the market. Electricity will not have a significant effect on the household heads' domestic work time because domestic workloads are partly diverted to the youth or children in the household. Although electricity should increase their leisure time, the burdens and responsibilities may

lead them to prefer work to leisure. However, in a household where most of the domestic work is diverted to the youth of the household and they contribute to the family burdens, electricity could have a positive impact on the leisure time of the household heads. The magnitude of the effect is likely to differ depending on the gender of the household head. This is because, unlike male-headed households where, in most cases, the burdens and responsibilities are shared with his wife, the burdens and responsibilities for a female household head are much greater ([Grogan and Sadanand, 2013](#)).

Adults For the adults in the household, it is assumed that these will be similar effects to those of the heads of households, but with a different magnitude. This can be explained by the fact that unlike the head of the household, who generally takes charge of the problems and burdens of the entire family, the “young adults” often takes charge only of themselves. In addition, when there are many “young” adults in the household, there is often a division of domestic tasks, and each one takes care of a specific task. They will therefore have more time for their leisure in case of electrification. Finally, even if the magnitude is different by gender, the sign of the effect should be identical.

Further implications We hypothesize that the allocation of time that occurs as a result of access to electricity could have various implications. One implication will be increased inequality within the household. For example, in households with couples, the increase in labor market time may be on the side of the head of the household, but not on the side of his or her spouse. This may result in an increase in income inequality between spouses induced by inequalities in working time in the market. Also, on the side of domestic work and leisure, the wife of the head of the household can gain in domestic work time and allocate it to leisure. To do this, we explore the inequalities in time (work, domestic, and leisure) and income that may result from access to electricity. Another implication will be increased labor force participation for adults, but a reduced one for children ([Bridge et al., 2016](#); [Salmon and Tanguy, 2016](#); [Khandker et al., 2013](#); [Dinkelman, 2011](#)).

1.4.2 Welfare

In order to fix ideas, we have so far shown that electrification can have effects on the allocation of time in households, by increasing working time (except for children) and leisure time, by making domestic production more efficient through the use of electrical appliances, and by positively affecting educational performance. These effects are, of course, conditionally constrained. In addition, electrification improves indoor air quality, and facilitates access to and development of other types of public infrastructure (e.g., hospitals, etc.). The final results are increased income, improved education, and health due to increased leisure time. These factors play an important role in well-being at the individual and household level. Thus, through time allocation, electrification will affect welfare.

1.5 Data

In this section, we present the data used to analyze the effects of electricity access.

To estimate the impact of electricity access on time allocation, we will use the 2018 Rwanda Labor Force Survey data. Rwanda is one of the smallest countries in Africa (see Figure 1.C1) with an area of 26,798km² landlocked by the Democratic Republic of Congo, Uganda, Tanzania, and Burundi (see Figures 1.C2 and 1.C3). It is a densely populated territory of about 12.3 million people (2018, according to WDI of the World Bank), composed of 5 provinces and 30 districts.

Over the past few years, the current government has carried out many decent work and economic development policy programs to achieve the goals in the first National Transformation Strategy (NST1), the Sustainable Development Goals (SDGs) as well as “*Vision 2020*” and “*Vision 2050*”. In order to evaluate its economic development efforts and the various programs carried out in the area of decent work, the government will use the results of survey statistics. The purpose of these surveys is to provide data on the structure and trends of employment and the labor force. The surveys are published by the National Institute of Statistics of Rwanda (NIRS).

Since 2016, Rwanda has started a rotating labor force survey program. This program covers an annual sample divided into two cycles (semi-annual) in order to provide quarterly estimates of key labor market indicators at the national level.

Beginning in 2019, the sampling frame was changed from semi-annual (February and August) to quarterly (February, May, August, and November) in order to provide estimates of labor market indicators and to monitor labor market trends on this quarterly basis. The surveys cover all persons living in private households in urban and rural areas of Rwanda, excluding the institutional population residing permanently in places such as hostels, health centers, correctional facilities, etc., as well as persons living in their place of work and in seasonal housing. The data cover labor force characteristics, employment and unemployment, components of labor underutilization, sectors of economic activity, the informal sector and informal employment, working time, labor income, women and equal opportunity, youth and education, and workers with disabilities (NISR, 2020).

In our analysis, we focus on data from the two rounds of surveys conducted in 2018, the first of which was in February and the second in August. We chose 2018 because of a change in the survey methodology and the fact that we were only able to access data from that year. Indeed, after August 2018, some modifications were adopted to accommodate a quarterly survey design starting in February 2019. These changes minimized disruptions from the previous survey design to maintain the same annual sample size. They resulted in a slight change in the sample size of households per primary sampling unit among sampled enumeration areas to ensure a smooth transition to the sample size required by the quarterly sample design (NISR, 2020). The results from the February round align with the results that would be obtained from pre-February 2018 statistics, and those from August 2018 align with results that would be obtained from February 2019.

These semi-annual surveys³, now quarterly, are designed using a stratified two-stage design with a rotation system. Under the survey's rotation scheme, each household in the sample is retained for four consecutive semesters or eight consecutive quarters before leaving the sample completely. In other words, the rotation is designed so that a household is followed over a two-year period before permanently exiting the survey sample. Thus, the sample for each survey cycle overlaps 75% with the previous survey cycle and 60% with the survey cycle from the previous year. The main purpose of the sample rotation is to control for sample variation

³Surveys conducted two times per year.

and thereby improve the precision of the estimates (NISR, 2018a).

Regarding the stratification scheme, these surveys are stratified in two stages. In the first stage of sampling, a stratified sample of 584 census enumeration areas is drawn from the latest census frame with probabilities proportional to the size measured in terms of number of households according to the latest population census. These census enumeration areas are called primary sampling units (PSUs). These PSUs are composed of the 30 administrative districts of the country, subdivided into urban and rural areas. In the second stage of sampling, a fixed number of households (16 households) are drawn from each sample PSU with equal probability, after a new list is drawn. All members of the sampled households are selected for the survey interview (NISR, 2018a).

The February 2018 survey uses a rotational sampling scheme with a sample size of 9,344 households per round, selected using a two-stage stratified probability design based on information from the 2012 Population and Housing Census. This information was updated in the second stage of sampling with a new list of new enumeration areas (NISR, 2018b).

The August 2018 sample design was used as a transition to the quarterly sample design for a quarterly survey beginning in February 2019. To accommodate a quarterly survey design that minimizes disruption from the previous survey design, the same modification was made to the August 2018 cycles. These changes resulted in a slight reduction in sample size in August 2018 to ensure a smooth transition to the quarterly design sample size requirement implemented at 530 PSUs instead of 584 PSUs (initially defined) (NISR, 2018a).⁴

1.6 Methodology

1.6.1 Method

To estimate the effect of electricity access on the distribution of time within households, we use a Spatial First Differences (SFD) approach. This approach was recently developed by Druckenmiller and Hsiang (2018). It overcomes the problem of estimating causal effects in regressions especially when important covariates, which

⁴To keep the number of households virtually the same, the sample size in 96 new enumeration areas was set at 24 households. This increased the sample size from 9,344 (584×16) to 9,248 ($96 \times 24 + 434 \times 16$) households in previous rounds.

may influence the outcomes (or the dependent variable) and are supposed to be correlated with the variable of interest (in this case access to electricity), cannot be observed and may lead to a significant bias in the estimation of the causal effect. The idea is to capture unobserved heterogeneity through non-stationary patterns in the results across space; and in the case where the spatial position of the observations can be located, the omitted variable bias due to this heterogeneity can be removed from the estimates using a simple and general differentiation approach ([Druckenmiller and Hsiang, 2018](#); [Robinson, 1988](#); [Yatchew, 1997](#)).

When the observation units are organized and highly geographically concentrated in physical space - such as gridded data or county-level data - the estimation is based on comparing individuals to their immediate neighbors and comparing all observations to a neighbor simultaneously. The underlying assumption of this approach is that immediately adjacent observation units are comparable to each other. Thus, by limiting comparisons of units to neighbors, the influence of any omitted variables that are common to neighboring units is differentiated. This procedure of analysis and differentiation by units with adjacent or nearby neighbors fundamentally transforms the identification assumption of cross-sectional analysis into one that matches those of modern quasi-experimental regression methods, especially the regression on discontinuity design.

The design of this method is relatively close to first differences in time approaches in panel data regressions to purge the data of unobserved factors specific to a panel unit. In the SFD approach, these specific unobserved factors are shared by two adjacent observations in space rather than time. Mathematically, the two approaches are identical, except that in SFD, the temporal index of observations is replaced by an index describing the position of observations in space.

Finally, this method is robust when the observations are organized and densely concentrated in space. When this condition is met, SFD approach also provides reliable results and better causal estimates when unobservable covariates are omitted and when instrumental variables are not available compared to cross-sectional approaches.

The major advantages of applying SFD method to the Rwanda data are explained by: the small size of the country, the condensed nature of the population, and the

quality of the survey data that allows for extrapolation of results to the country level.

1.6.2 Introducing the method

We first present the method developed by [Druckenmiller and Hsiang \(2018\)](#). Let the following specification be used:

$$y_i = x_i\beta + c_i\alpha + \epsilon_i \quad (1.8)$$

y is the outcome (output) variable, x a set of k observable variables, and c composed of m unobservable variables that could possibly influence the outcome y ; ϵ the error term assumed to be independent and identically distributed with a mean of zero; N the number of observation units indexed by i .

The β vector represents the set of estimated causal effects of the k parameters of interest. With Ordinary Least Squares (OLS) regression strategies, if the vector of variables c is omitted, then this results in an omitted variable bias, and the estimate of the β vector becomes biased. We denote this new vector β_L and the estimated regression becomes:

$$y_i = x_i\hat{\beta}_L + \hat{\epsilon}_i \quad (1.9)$$

And the “omitted variable bias” in the vector of parameter estimates is

$$E[\hat{\beta}_L - \beta_L] = E[(x'x)^{-1}(x'c\alpha)] \quad (1.10)$$

which may be important if the covariance between x_i and c_i is large and/or if one of the m elements of α is important. However, because c is unobserved, β_L is no longer used as a basis for causal inference, regardless of the number of covariates included in the regression model.

To circumvent this problem of causal inference in the case of omitted variable bias, several research designs have been developed. For example, in the case of impact evaluation methods, the challenge of causal inference requires researchers to use counterfactual outcomes to determine the effect of unbiased treatment β such as:

$$(x_i - x_j)\beta = E[y_i|x_i] - E[y_i|x_j] \quad (1.11)$$

under the assumption that

$$E[y_i|x_j] = E[y_j|x_j] \quad \forall i \neq j \quad (1.12)$$

where i is the individual who received the treatment and j is the counterfactual who could have the same outcome as i if treated.

This assumption, known as the *conditional independence assumption*, is relatively strong in many contexts. It assumes that all observational units in a cross-section of data are comparable. However, in the presence of unobserved heterogeneity, such as the unobservable variables described by c in equation (1.8), the assumption in equation (1.12) will not hold, as units i and j will no longer be comparable when conditioned only on their x 's.

Druckemiller and Hsiang (2018) proposes that the causal effect of x , β , can sometimes be credibly identified in the presence of unobserved variables c by reformulating the estimation procedure to compare only small differences in x and y between adjacent observation units. They suggest that this approach exploits a conditional independence assumption that is considerably weaker than that in equation (1.12), as the observational units are only compared to their immediate neighbors. In this case, if i is an index that corresponds to the order of observations in space within an arbitrary coordinate system, such that observations i and $i - 1$ are immediately adjacent to each other, then the SFD search design replaces the assumption in equation (1.12) with a significantly weaker assumption.

$$E[y_i|x_{i-1}] = E[y_{i-1}|x_{i-1}] \quad \forall \{i, i - 1\} \quad (1.13)$$

which states that the potential expected outcomes for two immediate neighbors ' i ' and ' $i - 1$ ' are equal if they received the same treatment x_{i-1} . According to Druckemiller and Hsiang (2018), this assumption, called the *Local Conditional Independence Assumption*, is a strictly weaker assumption than equation (1.12) because equation (1.12) applies to all pairs of observations in the sample, whereas equation (1.13) states that the same conditions apply only to the subset of pairs

where the observations are adjacent. It imposes that units are only conditionally independent with respect to their local neighbors. It is conceptually similar to several econometric assumptions, such as (i) the assumption that immediately sequential observations in a time series are comparable, allowing for time series first differences, (ii) the assumption that sequential observations within a panel unit are comparable, often used in panel “differences-in-differences”; and (iii) the assumption that observations just above and just below a treatment discontinuity are comparable, often used in discontinuity regressions.

In the design of the SFD, the mathematical procedure is identical to that of time series and panel first differences, and spatial cues will substitute for temporal ones.

Estimation by SDFs transforms equation 1.8 by spatially adjacent observations i and $i - 1$, then differentiating, we get:

$$\underbrace{y_i - y_{i-1}}_{\Delta y_i} = \underbrace{(x_i - x_{i-1})}_{\Delta x_i} \beta + \underbrace{(c_i - c_{i-1})}_{\Delta c_i} \alpha + \underbrace{(\epsilon_i - \epsilon_{i-1})}_{\Delta \epsilon_i} \quad (1.14)$$

where the operator Δ denotes differences by the index of the highest index of the pair of observations (i rather than $i - 1$) and is analogous to the difference operator in time series analysis. And since the c variables are unobservable, in reality the equation to be estimated is:

$$\Delta y_i = \Delta x_i \beta_{SFD} + \Delta \epsilon_i \quad (1.15)$$

The estimator in the cross-sectional OLS regression framework applied to the SFD context is

$$\hat{\beta}_{SFD} = (\Delta x' \Delta x)^{-1} (\Delta x' \Delta y) \quad (1.16)$$

and the local conditional independence assumption (equation 1.13) implies

$$E[\Delta x' \Delta c] = 0_{K,M} \quad (1.17)$$

indicating that the covariance between changes in x and changes in c between nearest neighbors are not systematically correlated within the population. Under this much weaker and more plausible SFD identification assumption than the OLS

one ($E[x'c] = 0_{K,M}$), the SFD estimate is unbiased.

1.6.3 Application of SFD to Rwanda survey data

The SFD estimation procedure is used to exploit this local conditional independence hypothesis by comparing each observation to a spatially adjacent neighbour. By making the first difference of each pair of neighboring observations, we purge the unwanted factors common to the pair. This method would be more effective on such data, because in developing countries, such as Rwanda, inequality in towns and villages or between towns and villages often leads to clusters of similar people in the same geographical area: the rich and educated in large cities and the poor and the less educated in the countryside.

In our study, we have information at the individual level in households of the two rounds of the 2018 labour force survey. The equation to be estimated is the equation (1.8). By using SFD method, the equation to be estimated becomes equation (1.15), and should, in our context, provide unbiased estimators.

$$\Delta y_i = \Delta x_i \beta_{SFD} + \Delta \epsilon_i$$

Where y is the outcome (output) variable composed of time in the labor market, domestic work time, and leisure time; x a set of k observable variables, composed of access to electricity, household size, education level, age; ϵ the error term is assumed to be independent and identically distributed with mean zero; N is the number of observation units indexed by i . The vector of coefficients β_{SFD} represents the causal effects estimated by SFD of the k parameters of interest. Δ denotes the difference operator of the pair of observations (i and $i - 1$).

Figure 1.D1 shows the spatial distribution of households with access to electricity or not for the two rounds studied, subs figure 1.D1a is for round 1 of February and sub-figure 1.D1b is for round 2 of August. The two sub-figures are slightly different because of the rotational structure of the investigations. There is a high concentration of electrified households in Kigali, the country's capital, and a somewhat random distribution in other districts.

Further, we detail the process of clustering neighboring units based on a fairly simple and intuitive algorithm. Our reasoning does not follow the logic of adjacent

units, as in the main article by [Druckenmiller and Hsiang \(2018\)](#), but rather a logic of neighboring units. The aim is to create clusters of neighboring units, in which close or neighboring units will be identified. Units can be considered as households or individuals, but the principle remains the same.

First, taking into account the fact that Rwanda is a small country, we divide the country into 25 bands of latitude and longitude, as on the Figure [1.D2](#). To define the 25 longitude bands as in latitude, we begin by defining 4 points/units or extreme households A , B , C , and D . Figure [1.D2](#) shows the geographical position of all the units, at the household level, that were surveyed during the two rounds of 2018 as well as these 4 extreme points. Extreme unit B represents the first household starting with the extreme south of the country, thus the one that minimizes latitude. At its opposite end, Unit D is the first household starting from the north, thus maximizing latitude. Then Unit A , which is located in the far west of the country, is the one that minimizes longitude. Finally, the C household finds itself in the far east of the country, maximizing longitude.

- *Process of clustering in Latitude West-East (Lat WE)*

The “Latitude West-East” clustering process involves, using latitude bands, or latitude clusters, creating clusters of neighbouring units. A band or a cluster in latitude is the first level of analysis. Then, within each cluster (band) of latitude, we create groups or clusters of neighboring units. The cluster of neighbouring units is the second level of the analysis. In the end, in each cluster of neighbors, we identify the neighbors by considering the most westerly unit as the first unit of the cluster ($i = 1$) and the cluster units ($i = \{2, 3, \dots, n\}$ for neighbors) that lie to the east as these neighbors, which we call the eastern neighbors. This is the third level of analysis. To put it simply, clusters in latitude are as classes in a school (first level), within which we have rows of seated students, the neighbor clusters (second level). And, within each row, we have seated students with number i and their neighbor has number $i + 1$. In our case, the first neighbor will be the westernmost one, and we count until the last easternmost one.

The algorithm is described as follows:

First, we will use the extreme units B and D . By using them, we define 25 bands in latitude. The stripes are bounded by brown lines on the figure [1.D2](#). Each

band contains a set of units, and extends approximately 7.617 km in latitude (in thickness), a difference of 0.137 degrees of latitude between the lines that delineate the latitudinal bands.⁵

Next, we define a neighborhood distance threshold at 15.234 km. The threshold is equivalent to the extent of two latitudinal bands, i.e. 2 times 7.617 km. Considering this threshold, we write a neighboring unit clustering algorithm. The algorithm chooses a first band, preferably the first lower band named “*Lat 1*”, and starts the clustering process from west to east, and considers two units as neighbors if the distance between them is less than the threshold. Otherwise, if two units are not considered as neighbors, then it splits these two units in two, and associates the unit in the west to the current cluster group, then starts a new cluster group with the unit in the east. For this new group, the algorithm repeats the procedure with two units until the last two units to the east. Then, it moves to a next band, the top band named “*Lat 2*”, creates a new cluster group, and continues the process of clustering neighboring units. At the end of the procedure, it returns each cluster within which there are units alone or with one or more neighboring units.

- *Process of clustering in Longitude South-North (Long SN)*

The “Longitude South-North” clustering process involves, using longitude bands, or longitude clusters, creating clusters of neighboring units. A longitude band (or cluster) is the first level of analysis. Then, within each longitude band, we create groups or clusters of neighboring units. The cluster of neighbouring units is the second level of the analysis. At the end, in each cluster of neighbors, we identify the neighbors by considering the southerner unit as the first unit of the cluster ($i = 1$) and the cluster units ($i = \{2, 3, \dots, n\}$ for neighbors) that lie to the north as its neighbors, which we call the northern neighbors. This is the third level of analysis.

The algorithm is described as follows:

First, we will use extreme units A and C to define 25 longitude bands. The stripes are bounded by blue lines. Each strip contains a set of units, and extends about 8.689 km in longitude (a gap of 0.137 between one line and the other in longitude). We assume here that 1 degree of longitude is equivalent to 111km.

⁵We assume here that 1 degree of latitude is equivalent to 111km.

Next, we set a neighbourhood distance threshold at 17.377 km. The threshold is equivalent to the extent of two longitudinal strips, twice 8.689 km. Considering this threshold, we write an algorithm for clustering neighboring units. The algorithm chooses a first band, preferably the first band to the west (left) named “*Long 1*”, and begins the clustering process from south to north. Two units are considered neighbours if the distance between them is below the threshold. Otherwise, if two units are not considered neighbors, then the algorithm splits them in two, and associates the southern unit with the current cluster group, then starts a new cluster group with the northern unit. With this new group, the algorithm resumes the procedure with two units up to the last two units to the north. Then it moves to a next strip, the right-hand band called “*Long 2*”, create a new cluster group, and continues the process of clustering neighboring units. At the end of the procedure, it returns each cluster in which one has units alone or with one or more neighboring units.

- *Clustering at the household level*

Below, we describe the results of the application of the algorithm on Rwandan data. The results of a clustering in “Latitude West-East” are shown respectively in figures 1.D3a and 1.D4a for rounds 1 and 2 by considering units as households, and Figures 1.D3b and 1.D4b for a clustering in “Longitude South-North”. Table 1.D1 shows the results for round 1 and round 2 respectively in columns (1) and (2). Panel A presents the results by clustering in “Latitude West-East” and panel B for a clustering in “Longitude South-North”.

For round 1 with 8469 households, by clustering in latitude, we obtain 54 clusters of neighboring households. The number of households within clusters varies between 1 and 2313 households. On average, clusters have 425 households and 50% of neighbor clusters have at least 149 households. Clustering in longitude, we obtain 34 neighboring household clusters. The number of households within clusters ranges from 1 to 1475 households. On average, clusters have 345 households and 50% of clusters have at least 189 households.

For round 2 with 8588 households, by clustering in latitude, we obtain 61 clusters of neighboring households. The number of households in the clusters varies between 1 and 2328 households. And on average, clusters have 415 households, and 50% of

clusters have at least 132 households. Clustering in longitude, we get 37 clusters of neighboring households. The number of households within clusters varies between 1 and 1420 households. On average, clusters have 341 households and 50% of clusters have at least 189 households.

On average, the clusters have relatively large household sizes, between 415 and 425 households, and similar between round 1 and round 2. This size is well suited to the application of SFD method.

- *Estimation strategy*

Based on our three-level clustering process, we retain two levels, the second and third levels. In other words, we drop the bands in latitude (level 1) and use the created neighbor clusters (level 2) and neighbor position identification (level 3). By retaining these two levels, our approach becomes similar to an estimation in panel data.

In a classical panel specification, our linear equation to be estimated would be:

$$y_{ij} = x_{ij}\beta + z_{ij} + \epsilon_{ij} \quad (1.18)$$

y is the output variable composed of work time, domestic work time and leisure time; x is our variable of interest which takes 1 if the unit has access to electricity and 0 otherwise; z is a vector of k observable control variables, composed of the characteristics of the unit (household and/or individual) such as household size, education level, age, etc., which could possibly influence the output y ; ϵ is the error term assumed to be independent and identically distributed with a mean of zero. The index i represents the cluster of neighboring units, j represents the position of the unit in cluster i . These indices are similar to those used in classical panels, where i represents the unit, often the country, or j represents the time.

Due to the unobservable variables that could impact the result y , estimation by the classical panel method would lead to an estimation bias due to the unobservable variables. SFD approach overcomes this problem and the equation to be estimated is:

$$\Delta y_{ij} = \Delta x_{ij}\beta_{SFD} + \Delta z_{ij}\alpha_{SFD} + \epsilon_{ij} \quad (1.19)$$

Where Δ represents a difference operator. In our framework, we just use the first difference. We compute the difference between a unit j and its neighbor $j - 1$ within cluster i , such that, as an example, $\Delta y_{ij} = y_{ij} \smile y_{ij-1}$.⁶ This method eliminates bias problems and leads to causal inference of the β and α estimators.

It is true that the use of instrumental variables could help us, but finding the right for instruments (Dinkelman, 2011; Grogan and Sadanand, 2013; Khandker et al., 2013; Van de Walle et al., 2013; Salmon and Tanguy, 2016) is not easy. Most commonly used instruments are all criticizable (Barron and Torero, 2014). Hence, instead of looking for good instrumental variables, we look for a method that would be more efficient, as the SFD.

This method allows us to verify previously advanced arguments such as: (i) clusters of similar individuals (e.g., rich or well-educated) may be created due to growing inequalities, (ii) the underlying assumption that immediately adjacent observation units are comparable to each other, (iii) the capture of unobserved heterogeneity through non-stationary trends in results across space, and (iv) the possibility of eliminating bias due to omitted variables through this heterogeneity using a simple and general differentiation approach (Druckenmiller and Hsiang, 2018; Robinson, 1988; Yatchew, 1997). To verify all this, we create an indicator of household wealth using the principal component analysis method to examine how it varies across neighboring units in the space (Rutstein and Johnson, 2004).

The results are presented in Figures 1.D5 and 1.D6 for rounds 1 and 2 respectively. The factor axes 1 that we use as an indicator of wealth unfortunately have a small share of the variance explained (10.5% for round 1, or even the sub-figure 1.D5b, and 10.9% for round 2, see the sub-figure 1.D6b). We analyze this indicator and access to electrification. There is a high concentration of unelectrified individuals to the left of axes 1 (the green circle) characterizing poor individuals and a high concentration of electrified individuals on the right (blue circle) characterizing wealthy individuals.

We present the evolution of this wealth indicator in level and first difference.

⁶It should be noted that in the presentation of the paper we write $\Delta y_{ij} = y_{ij} \smile y_{ij-1}$ to be consistent with the usual econometric notation. But in practice it is $\Delta y_{ij} = y_{ij} \smile y_{ij+1}$. Because we assign a higher value to a neighboring unit. For example, a unit whose position value is $j = 1$, its neighbor takes the position $j = 2$.

The unit j of cluster i in this example is defined at the household level.⁷

Figures 1.D7 and 1.D8, for rounds 1 and 2 respectively, show how on average the wealth indicator changes from one household to its neighbor, and the difference in wealth level between a household and its first neighbor. Subfigures (a), in particular 1.D7a and 1.D8a, result from a “Lat WE” clustering process, while subfigures (b), in particular 1.D7b and 1.D8b, result from a “Long SN” clustering process. On each sub-figure, Graph *A* shows the variable on average for the neighbour clusters in Rwanda. On the x-axis, we have the positions of the neighbours. Graph *B* shows the variables in first difference (i.e. a difference at the first nearest neighbour). The green red line (dashed) cuts the first 200 neighbouring units from the others, and we present “zoomed” graphs of the first 200 neighbouring units in Graphs *C* and *D*. Graph *C* shows the variable in mean for the first 200 neighbouring units of the clusters, and Graph *D* shows the variables in first difference (i.e. a difference at the first nearest neighbor) for the first 200 neighbouring units.

From this example, which supports our previous arguments well, we also note the presence of spatial autocorrelation for this income level indicator. In other words, wealthy households tend to be neighbors, just as poor households also tend to be neighbors.

It is important to note that when we pass the variables in first difference, the averages of the variables are now statically equal to zero (via a test of Student, Table 1.D2). This exercise reinforces the fact that the primary difference between neighbouring units would easily and possibly eliminate non-observable characteristics, and eliminate bias due to all unobservable variables correlated in space specific to neighbouring units.

1.6.4 Definition of variables

Our variables are working time in the labour market, here called “Labor market time”, domestic working time, called “Home time” and leisure time called “Leisure time”. Domestic working time consists of two time allocation groups. For the first group, the time for the production of domestic goods entitled “Time for goods” is

⁷Even though we implement the same example for all the variables to be introduced in the model, we do not present these results in this paper in order not to burden the reader. The results are available upon request from the authors. Instead, we present a table testing whether the mean of the variables is statistically different from zero or not, Table 1.D2.

the set of times aggregated base on the surveys: spent collecting firewood for the household, including travel time; spent fetching water for the household, including travel time; spent looking for fodder or pasture for household animals; and finally devoted to the manufacture of household items for personal or family use (such as furniture, textiles, clothing, shoes, pottery, crafts or other durable goods, excluding food). The second group, the time for the production of domestic services entitled “Time for services”, constitutes all the times: spent building housing, carrying out major repairs, agricultural buildings and private roads; moved on to household chores, including shopping, meal preparation; spent caring for children and the elderly. These times are expressed in hours and calculated over a weekly period.

Leisure time is defined as the difference between the total number of hours per week ($24 \text{ hours} \times 7 \text{ days}$), from which we subtract domestic working time and working time in the labor market. This time is further reduced by 40 hours ($8 \text{ hours} \times 5 \text{ days}$) for individuals who report being enrolled in pre-university studies and by 30 hours ($6 \text{ hours} \times 5 \text{ days}$) for those studying at university. This adjustment is made because, in line with the literature, time spent studying cannot be considered leisure time. We acknowledge that this measure of leisure time has significant limitations. Even if we wanted to take into account certain individual characteristics (such as excluding time spent studying at home for children, doing homework with children for parents, etc.) to create a better indicator of leisure time, this would complicate the task without necessarily providing a more accurate measure.

Our processing or interest variable here is “Electricity” which is a binary coded variable taking 1 if the unit (or household) is connected to electricity and 0 if not.

Our control variables include age (Age, expressed in year), household size (HH size), number of children of 13 and under (Num. of children), level of education (Education, expressed in year at school), number of rooms per head of household (Rooms per capita), a binary variable taking 1 if the household has a domestic help or servant, or 0 if not (Domestic Helper). These variables are very likely to have an impact on working, domestic and leisure time. The size of the household is the number of people who make up the household.

1.7 Descriptive analysis

Descriptive statistics on key household and individual characteristics are reported in Table 1.E1. The table shows similar statistics for round 1 and round 2. After processing data, especially missing data, the statistics will cover a sample of 8469 households for round 1 and 8588 for round 2, which is representative respectively for about 2698556 households and 2608177 households in the Rwandan population. At the individual level, there were 36369 individuals in round 1 and 36839 individuals in round 2, respectively representative for approximately 11287896 individuals and 11667250 individuals.

Regarding access to electricity, 29.68% of households in round 1 had access to electricity, compared to 34.16% in round 2, representing a significant increase of 4.48 percentage points ($p\text{-value} < 2.2\text{e-}16$). Using the provided weights for households and individuals, we will apply these weights to each unit before conducting the analyses. Based on weighted data, approximately 32.81% of individuals had access to electricity in February 2018 (round 1), rising to 37.28% in August 2018 (round 2). This indicates an increase of about 4.46 percentage points in individual access to electricity between the two rounds, equivalent to an estimated 138,891 additional households connected to electricity in the population.

With regard to the allocation of weekly time, for each time variable, Table 1.E1 reports the average time at the individual level. On average, the average weekly working time in the labour market is about 39 hours, 38,318 in round 1 and 39,695 in round 2. The average domestic time is about 14 hours, 9 hours for the production of domestic goods, and, 10 hours for the production of domestic services. Finally, the amount of time spent on leisure is about 129 hours per week.

In general, the study population is extremely young with an average age of 24, and households are composed of an average of 5 people. The households contain about 2 children under the age of 13, and just 1 young person between the age of 14 and 17. The average number of years spent in school is about 13 years, which implies that individuals have on average the secondary level. The same statistics is relatively similar for the level of education of the head of households. The average income of an individual is about 14,000 Rwandan francs per week, and on average households have a total of 23,000 francs per week for an average per capita income of

about 4600 francs per week. The average number of rooms in households is between 2 and 3, with one room for every 2 people on average. And, nearly 52% of the population is female. Only 1.5% of the population has help or domestic servants.

A comparative analysis of individuals in connected households compared to those in non-connected households shows that individuals in connected households spend on average more hours in the labour market (14 hours more), and more time for the production of domestic services (about 1 hour more) than those of non-connected households. Nevertheless, they spend fewer hours for domestic production (about 4 hours less) and the production of domestic goods (3 hours less). The analysis also shows that connected people allocate more time in walking work, also simultaneously gaining time in domestic production time (time for the search for firewood, to the manufacture of tools and household goods ...), while increasing the time of provision of services (housing construction, household chores of meal preparations, and the care of children).

In addition, we will conduct a gender-based comparative analysis. The results are reported in Table 1.E2 for adults, i.e. those aged 18 and over. In general, men work more hours than women in the labour market, 42 hours compared to 35 hours. On the other hand, women spend more hours producing domestic goods and services than men. Total domestic production (goods and services) accounts for 23 hours for women compared to 9 hours for men, including 18 hours for women compared to 7 hours for men for the production of domestic services.

As far as the production of domestic goods is concerned, there is no difference between the time spent by men and that of women. Leisure time is higher for men than for women. The average age for adults is between 37 and 38 years, and the age gap between adult men and women remains relatively small, just 1 year. The same facts are observed in terms of education. The average number of years spent in school is 11 years, and the gap is very small comparing men and women. However, men earn much more income than women.

Now we will analyze individuals in households connected to electricity compared to individuals in unconnected households within each gender group. First of all, it should be noted that, regardless of gender, the comparison of connected people versus unconnected people provides relatively the same results or signs (but not with

the same magnitude, except leisure time).

The number of hours worked in the labor market for electricity-connected workers is higher on average compared to non-connected workers, especially for women (16 hours) compared to men (12 hours). Domestic working hours in general, and in the production of domestic goods in particular, are lower among connected individuals than among the unconnected. The difference is almost 5 hours for men and about 4 hours for women. Nevertheless, connected women spend more hours on the production of domestic services, while for men, there is no significant difference. In examining leisure time, it is important to note that there is little evidence of a time difference between electrified and non-electrified individuals, though among women there is a positive difference. Women in electrified households allocate 2 more hours to leisure time compared to non-electrified ones. In both gender groups, electrified individuals are often younger, more educated, and earn higher incomes than non-electrified individuals.

An analysis on young people and children will also bring interesting insights. To do this we show descriptive statistics on the under-18s. The results are carried over to Table 1.E3. This table shows relatively similar working time in the market for girls and young boys (between 24 and 27 hours per week). In fact, for children, data on working time and income are only available to young people between the age of 14 and 17. The average age is about 8 years. The level of education and leisure time of connected children are slightly higher than those of unconnected children. There is a considerable gap between the working time of young people in the labour market, but it is noted that connected girls work more hours than those not connected, however the difference among boys is not so robust. Girls spend more time in domestic work than young men, but access to electricity decreases in the same proportion this time of domestic work (about 5 hours of time).

Looking at the production time of domestic goods, it should be noted that boys and girls have relatively the same durations (about 7 hours). Children with access to electricity spend on average less time in the production of domestic goods than those who are not connected. Although girls tend to spend more time in the production of domestic services than boys, it should be noted that in these two groups, those connected to electricity spend fewer hours in the production of services than those

not connected. Moreover, although in both groups the revenues are relative to around 3500 Rwandan franc (RWF), it should be noted that there is no evidence of a gap between those connected and those not connected.

In summary, for individuals in households that have access to electricity compared to non-electrified households, the time allocated to the labour market is higher, with the exception of young boys between the age of 14 and 17, of whom there is no major difference. The magnitude of this difference is more pronounced for individuals of the female gender than of the male gender. On the other hand, there has been a decrease in domestic working time, and in particular, the time given to the production of goods among electrified people than among non-electrified. This decline is more pronounced for adult men and boys than in adult women and girls. Considering the production time of domestic services, there is an increase for adult women, but a decrease for children in electrified households. Finally, while leisure time generally increases, the evidence remains weak among men.

The main findings of these descriptive statistics support our theoretical model, which argues that access to electricity is associated with changes in household time. Electricity is associated with an increase in working time, leisure time and saves domestic time by reducing the main activities of finding firewood for the household, including travel time, manufacturing of handicrafts or durable goods for personal or family use. But it is associated with an increase in the production time of domestic services. Households are more involved in building their homes when they are connected to electricity.

We summarize in Table 1.E4 the signs obtained from the descriptive analysis (Column: *Sign obt.*) that we compare with the signs we expect to get (Column: *Hyp.*). The results of this comparison are reported in the column “*Verified?*” that takes Yes, if it is verified, and No, if not. It should be noted that the descriptive analysis supports many of our assumptions with the exception of the effects on working time of children in the market and the effects on adult men’s leisure. We believe that the results for adult men will be the same as for household heads. And we believe that these changes will also affect inequalities in time distributions and income inequality.

However, we have so far not estimated the causal effects of access to electricity

on time allocation and inequalities. This will be the objective of the next section.

1.8 Empirical results, discussion and robustness

In this section we present the empirical results of our specification. We estimate the effects of electricity on the distribution of working time using the SFD method. In addition, we apply the standard error correction procedure proposed by [Conley \(1999\)](#)⁸ in all our regressions to take into account disturbances in the estimation that may be due to spatial autocorrelation, as well as the weights of the study units in order to be able to infer the results at the population level.

1.8.1 Analysis at the household and household heads level

- *Analysis at a household level*

First, we focus on analysis at the household level. This household-level analysis is necessary to understand the effects of electricity on households as a whole instead of an individual in the household. To analyze the average time allocation within a household, we calculate the average time allowed for each type of activity (work, domestic, leisure, domestic production of goods or services) in a household. For example, the average working time of a household is equal to the average time of the people who work in that household. We also control for age, household size, number of children in the household, level of education, and gender, and other household characteristics, such as the number of rooms per head and the presence of domestic help. Given that in African societies, the head of household is often given a significant weight⁹, we integrate the age, level of education and gender of the head of household instead of calculating their average value in the family.

The results are shown in Table 1.F1. An important point to make is that the type of head of household impacts the average working time, the average leisure time and the average time of production of services in the household¹⁰. This strongly supports the idea of the difference in time allocation by gender. The results on the gender

⁸We work on R and Stata software, and for [Conley \(1999\)](#) spatial autocorrelation correction, we implement the code developed by Darin Christensen: <https://github.com/darinchristensen/conley-se> (version 2017).

⁹Indeed, in developing societies, the head of household often gives the instructions to follow and respect in the family and has an important power of decision-making.

¹⁰Based on this remark, in addition to the results of descriptive statistics that show major gender differences, we try to analyze whether the impact of electricity or other control variables is different on the distribution of average time in households by gender of the head of household.

analysis are reported in Table 1.F2 for households with a male head, and in Table 1.F3 for households with a female head.

In the different tables, we present 4 types of regression for each variable with the aim of supporting the *robustness* of our results and conclusions. The 4 regressions are divided into 2 for each survey round (see the line “Round” in the tables). For each round, a first regression is estimated using the “Latitude West-East” (or “Lat WE”) clustering process, and a second by using the “Longitude South-North” clustering process (“Long SN”). Overall, the explanatory power of our explanatory variables is acceptable. Indeed, the R-square is between 26% and 60%. We have a large number of clusters of neighbouring units that range from 33 to 61. The number of cluster groups is small when using a “Long-SN” clustering process compared to the “Lat WE” clustering process.

Overall, we notice that the signs of effects (coefficients) remain the same, but their magnitudes vary by gender, and especially at the level of variables such as the number of rooms per head and the possession of a household help.

A review of the three tables (1.F1, 1.F2 and 1.F3) shows that access to electricity has a positive effect on the average working time in the household labourmarket. Access to electricity increases the average time on the labour market in the household from $4\frac{1}{2}$ to 5 hours per week. The effect is relatively larger but not robust in households with a female head of household (up to 5.5 hours, see Table 1.F3) compared to households with a male head of household (up to 4.7 hours, see Table 1.F2). This difference can be explained by the fact that in households where the heads are men, there is also very often his spouse. In other words, households whose heads are male are often two-parent. The presence of his spouse loosens the budgetary constraint of the household. The latter often provides financial support to the needs of the family. And so, even if the man has to work more hours in the labour market, he only gives the time necessary to pay for additional expenses (e.g. electricity bills). It does not really need to increase the hours given to the labour market very strongly. Households in which heads of households are women are very often single-parent. Therefore, to meet the needs of the family alone, and to bear the additional costs of not having a spouse at home (paying nannies to look after the children), they greatly increase the working time in the labour market.

For domestic production (including goods and services), access to electricity tends to reduce the average production time of domestic goods and services by about one hour (Table 1.F1).

This reduction is much greater in households where the heads are women (at least 1.3 hours per week, see Table 1.F3) compared to households whose heads are men (just 1 hour on average, see Table 1.F2). The explanation for this difference can be explained as follows: First, access to electricity itself often leads to the purchase and use of goods, household items and tools (cooking plates, refrigerators, etc.) that replace handmade goods (wood-burning fireplaces). This substitution saves domestic time by reducing the time allowed to search for firewood, including travel time, etc. Second, the composition of the household is also important. In households where the heads are men, usually two-parent households, the production time of goods and services decreases but not sharply, as the use of traditional means persists. It is true that this type of household acquires new tools and goods intensive in electricity, but their use can be moderate in order to limit expenses (e.g. electricity consumption costs). Unlike households where the heads are women, often single-parent, the use of electrically intensive goods is crucial to save time and work in the labour market in order to meet the needs of the family. Handcrafted goods and tools that consume more time are less used.

However, leisure time in a household is not significantly impacted by electricity contrary to the predictions of our theoretical model.

We further explore how access to electricity affects the allocation of average production time for domestic goods and services. In terms of the average production time of domestic goods, access to electricity has a negative effect. Electricity reduces this time by about 1 hour (Table 1.F1). The reduction is between 1.2 and 1.5 hours in households with male leaders (Table 1.F2), and 1.4 hours, but not robust among households with female leaders (Table 1.F3).

Nevertheless the effect of access to electricity is positive on the average time of production of domestic services. Access to electricity increases the average production time of domestic services by about 0.8 to 1.3 hours (see Table 1.F1). The increase is between 1.1 and 1.7 hours in households with a male head of household (see Table 1.F2), but there is no significant effect in households with a female head

of household (Table 1.F3).

These latter elements corroborate our previous results of the effect of electricity on production time. Further explanations can be deduced. Access to electricity leads to the use of energy-intensive goods and tools, and thus saves time due to the substitution of these tools for traditional and artisanal tools that consume in time. And the use of intensive electricity tools leads to a quick production of goods and services. For example, making a meal with an electric plate will be faster than making a meal with a fireplace using firewood. The fact that the single-parent composition of the household does not have a significant impact on the production time of services among households whose head of household is a woman can be explained once again. The time saved is not felt because they (heads of the household) do not have a spouse to assist him in the shopping, the construction of housing, important repairs, household chores, caring for the children...¹¹

With regard to the control variables introduced in the model, it is noted that the age of the head of household (*i*) has a negative impact on the average working time in the market, total domestic work, and particularly the average time of production of domestic services, but (*ii*) positively impacts the average leisure time and the average time of production of domestic goods. A possible explanation for the positive effect on the production of goods may be that in households where the head of household is elderly, most of the goods needed for the household are already acquired and it is just necessary to use and maintain them (shoe polishing, grazing animals ...) or spend time replacing them (especially artisanal goods), unlike a household where the head of household is young. The latter must make more effort to build up its assets. And so the young head of household provides more time in the labour market, and less effort for domestic services. So the old heads of households enjoying their acquired assets can spend time at leisure.

As for household size, the effect is positive on the average working time in the labor market but negative on the average time spent on domestic work (total, goods, and services) and average leisure time. A possible explanation is that the more people there are in a household, the more domestic work is required, and the more individuals need to work in the labor market to support the household. However, the

¹¹An analysis of married and single-status households is important to shed light on this explanation.

size effect would ideally lead to a better distribution of domestic work (production of goods and services), allowing individuals to gain leisure time. For example, household chores are completed faster when there are several individuals in the household to divide the tasks compared to when there are fewer. However, the results show that household size actually reduces leisure time.

The number of children aged 13 and under has a negative impact on the average working time in the labour market, but has a positive effect on the average time of domestic production, and the average leisure time. Indeed, at these ages, children require important attention from parents and adults; they must be occupied and monitored. This reduces working time in the market and leads to an increase in domestic working time and also in the family's leisure time. The level of education of the head of household has a positive effect on the average time of work in the market, and a negative effect on the average leisure time. But the latter is not very robust. There is no significant effect on domestic production time, with the exception of a positive effect on the production of domestic services.

It is very interesting to point out the role of domestic help. Having domestic help increases the average working time in the labor market and decreases total domestic working time, particularly in the production of domestic goods. However, the positive effect on leisure is not robust. The presence of domestic help in the household increases the average working time by up to 10 hours per week. This increase amounts to up to 7.5 hours in households with a male head of household, and up to 19 hours when the head of household is a woman.

All in all, it should be remembered in a household that access to electricity has a positive impact on working time. It loosens the constraints of domestic production time (total, goods, and services) but has no effect on household leisure time. Electricity is an element that contributes to the well-being of households, with more robust effects in households whose heads are male, and with greater magnitudes when the head of household is a woman. A possible explanation of the non-significant effect on leisure would probably be due to the measurement of this variable.

- *Head of household analysis*

In this part, we are only interested in household heads. In the types of developing societies we study, household heads often take full weight on the family. They are

very likely to be affected if electricity has an impact on the well-being of the family. Regressions are the same as before, except that dependent variables are represented by the time spent for each type of household activity. We always incorporate the same control variables. The results are presented in Table 1.F4 for all heads of households, in Table 1.F5 for men, and in Table 1.F6 for women.¹²

The various tables (1.F4, 1.F5, and 1.F6) show that access to electricity has a positive effect on the working time of the head of household. Access to electricity increases working time of the head of household in the labour market by up to 7.6 hours per week. The effect is even more robust in households where the head of household is a man, up to 9 hours per week. On the other hand, among women in charge of households, we notice a positive effect that is not very robust, up to 11.3 hours per week. This is quite surprising, but this low robustness is in line with that of previous results on households whose head of household is a woman.

Indeed, this can be related to the method more than from the data. SFD method assumes that the observations are geographically dense. This geographically dense distribution is not verified among female household heads. In addition, SFD method also applies a primary difference between neighbouring observations, which reduces the total number of observations, due to the suppression of observations that do not have a neighbouring unit. The total size of the database is shrinking. This impacts the results in female household heads (Table 1.F6).

To go further, we try a simple panel regression with both levels. The first level is the cluster (like countries) and the second is made up of neighbouring units (such as years). Here we have an unbalanced panel as the clusters do not have the same number of neighboring units. We estimate simple panel regressions with fixed or random effects, for each round (1 and 2), and by cluster types (“Lat WE” and “Long SN”).

The results are reported in Table 1.F8 for working time in the market for women and Table 1.F7 for men. We observe that electricity has a positive effect on working time. Columns (1) to (4) are for round 1, and columns (5) to (8) are for round 2.

¹²Overall, the explanatory power of our explanatory variables is acceptable; R-square is between 25% and 72%. The number of observations in relation to the number of clusters shows that we have a relatively large size on average per cluster. It is also noted that the signs of effects (coefficient) remain the same from one table to another, but the magnitude varies by gender, and particularly at the level of variables of household wealth level.

Columns (1), (3), (5), and (7) are fixed-effect estimates, while columns (2), (4), (6), and (8) are random-effect estimates. Columns (1), (2), (5), and (6) use a “Lat WE” clustering process to create clusters of neighboring households, and the remaining columns use a “Long SN” process. The results show that access to electricity has a positive impact on working time in the market. The magnitude of the effect increases to 12.9 hours per week for women and 11.1 hours per week for men. However, these results are open to discussion due to a set of unobservable heterogeneous effects that could lead to an endogeneity problem.

Access to electricity has no ‘robust’ effect on the domestic working time of household heads, both male and female. A possible explanation is that the authority of household heads allows them to assign domestic work to younger household members rather than performing the tasks themselves. For example, mothers may assign the cooking of family meals and housework (e.g., washing dishes) to the eldest or youngest daughters in the household to prepare them for married life, while fathers may assign tasks such as gathering firewood and herding to the older or younger sons in the family. In the future, an analysis that distinguishes between older and younger household members will be necessary to clarify this point.

The effect on leisure time is negative. Electricity reduces the leisure time of household heads by up to 5.6 hours. This effect extends 7.1 hours among male heads of households, but none for female household heads. Here we notice a substitution in leisure time and working time in the labour market. In other words, time lost in leisure is given to work in the labour market.

This analysis should suggest at the individual level that access to electricity produces an increase in working time for household heads, a reduction in leisure time, but no robust effect on domestic work times (total, goods or services). Our analysis implies, until now, that the positive effect of electricity on well-being is more robust collectively at the household level than at the individual level of household heads, even if household heads sacrifice their leisure time to focus more on work and earn more income. And the effect is more important for heads of household who are men. At this point in the analysis, we cannot conclude that electricity harms well-being, but rather contributes to it, and especially for male household head.

1.8.2 Inequality analysis

Now we will further to analyze whether access to electricity can be a source of inequality. In the first part, we explore inequality in the allocation of working time, followed by income inequality between household heads. As the impact of access to electricity has a different effect on working time by gender; we will also explore income inequality in a second part. We put a focus in particular on inequalities between heads of households. To calculate the inequality variable for each time or income variable, we simply calculate the absolute difference between the head of household and his or her spouse. Therefore, this analysis only takes into account households in which the head of household has a spouse.¹³

- *Inequality of time allocation*

The results on the inequality of time allocation are presented in Table 1.F9. For most of the different regressions, the explanatory power of the model is acceptable.¹⁴

With regard to inequality in working time in the market, access to electricity and the gender of the head of household can be seen as factors increasing inequality. The gap in working time between the head of household and his spouse due to electricity can increase to 7.6 hours per week. However, these results are weakly robust. Even if the four coefficients are positive, only one is significant. Nevertheless, for other forms of inequality (leisure time, total domestic work, goods or services), the coefficients change signs and three out of four coefficients are not significant. We conclude that there are no significant effects.

An examination of the factors of inequality of domestic working time shows that access to electricity is enhancing inequality. On the other hand, the age of the head of household and the size of the household are factors that reduce inequality, while the number of children increases the inequality of domestic work (total, production of goods, or production of services). In other words, if the number of children aged 13 and under increases, this leads one person (the head of household or his spouse) to devote more to domestic work (total, production of goods; and especially production of services). One more child widens the inequality gap by about 3 hours per week, while an additional individual in the household narrows the gap by about 2 hours.

¹³This naturally excludes widowed or divorced households and single-parent households.

¹⁴The R-square range from 23% to 84%.

Finally, it is noted that the main factor that increases time inequality, particularly inequalities in domestic working time, especially the production of services, as well as leisure time, is the number of children under the age of 13. The age of the head and the size of the household reduce these inequalities.

It should be remembered that access to electricity can lead to an increase in inequalities in working time in the labour market, but this result is not robust. Inequalities in domestic production time (total, goods, or services) and leisure do not seem to be explained by access to electricity.

- *Income inequality*

The results on income inequality between the head of the household and his spouse are presented in Table 1.F10. Although all coefficients are positive, only one in four is statistically significant. This table shows that access to electricity can lead to income inequality between a head of household and his or her spouse, but the results are not robust. It is very likely that income inequality will be partly explained by inequalities in working time in the market.

1.8.3 Analysis of adults and children

In this section, we present the analyses at the level of adults and children. However, the analysis of adults and children raises questions. There may be several adults and children in the same household. And, let us remind that, our algorithm is to analyze the units and their immediate neighbors by differentiating the observations between a unit and its neighbor. In its basic design, once the unit is defined, for example the “head of household”, the algorithm selects the “head of household”, and neighbouring household heads and makes a primary difference in their observations. Therefore, if the defined unit is “child” (“adult”), the algorithm will have to choose a “child” (“adult”) and go looking for a neighbouring “child” (“adult”) in neighbouring households. But when there are several “children” (“adults”) in two neighbouring households, there are several options available to the algorithm. In this case, a “child” (“adult”) may have several “children” (“adults”) neighbouring, while one must take only one per household to make the first difference between neighbours.¹⁵ There are two options to solve the problem. A first solution would

¹⁵For a concrete example, if the unit defined is “child”, the algorithm must choose a child at random and no longer consider his siblings, and then go and look for a neighbouring child. And,

be to calculate a “child” (“adult”) representative of a household when there are several children in the household. The second solution would be to use all possible combinations of children and their neighbouring children.

We opt in part for the second solution, which will follow a resampling approach, similar to Bootstrap’s method. It supposes iterating the random draw calculation with discount 1000 times. In other words, the algorithm starts with a first iteration. It randomly draws a “child” (“adult”) at random in all possible households, then makes an estimate by SFD method, and recovers the estimated coefficients. Then the algorithm switches to iteration 2. It makes a new random draw with the delivery of a “child” (“adult”) at random in all possible households, then makes an estimate by SFD method, and recovers the estimated coefficients again. The procedure is repeated up to 1000 iterations.¹⁶

Moreover, the analysis makes 1000 iterations for each type of clustering (“Lat WE” and “Long SN”) and for each round (1 and 2). In the end, we have 4000 iterations (2 rounds $\times$ 2 clustering types $\times$ 1000 iterations) for each variable. This reinforces the robustness of our results.

- *Presentation of the estimation method*

Our approach to estimating the effect of electricity on a unit such as “adult” or “child” is to perform n iterations of random resampling with resetting of the unit (“adult” or “child”) within the neighboring households. In this paper, n equals 1000 for each clustering type and round. At each iteration, we estimate β_{SFD} with a standard error $se(\beta_{SFD})$. At the end of the n iterations, we have n coefficients $\{\hat{\beta}_{SFD}^1, \hat{\beta}_{SFD}^2, \dots, \hat{\beta}_{SFD}^n\}$ with n standard errors $\{se(\hat{\beta}_{SFD}^1), se(\hat{\beta}_{SFD}^2), \dots, se(\hat{\beta}_{SFD}^n)\}$.

We now aim to have an “average” estimator of the effect of electricity on the time allocation of the unit under consideration (“adult” or “child”) from the n estimated coefficients such that

$$\hat{\beta}_{SFD}^m = \frac{1}{n} \sum_{i=1}^n \hat{\beta}_{SFD}^i$$

it is after that that it can make the difference between the neighboring children. However, this strategy of analyzing children could lead to misleading results. Because if you use a 9-year-old (A) and a 12-year-old neighbour (B) who has a 7-year-old brother (B'), you won’t necessarily find the same results compared to using the same 9-year-old (A) and the 7-year-old brother (B') of the neighbour who is 12 years old (B).

¹⁶It should be noted that this is a draw with discount, so a selected (adult) child can be back to the next iteration. And when there is only one child (adult) in a household, that child (adult) is always selected.

with a standard error

$$se(\hat{\beta}_{SFD}^m) = \frac{1}{n} \sum_{i=1}^{i=n} se(\hat{\beta}_{SFD}^i).$$

Note that our estimation approach is relatively similar to, but different from, a bootstrapping approach. In an ordinary bootstrapping approach, the “average” estimator would be the same as our estimator

$$\beta_{SFD}^m = \frac{1}{n} \sum_{i=1}^{i=n} \beta_{SFD}^i$$

but with a standard error

$$se(\beta_{SFD}^m) = \sqrt{\frac{\sum_{i=1}^{i=n} (\beta_{SFD}^i - \beta_{SFD}^m)^2}{n - 1}}.$$

Our simple resampling estimator is more efficient than a simple bootstrapping estimator. It is even better if we assume that the coefficients $\{\hat{\beta}_{SFD}^1, \hat{\beta}_{SFD}^2, \dots, \hat{\beta}_{SFD}^n\}$ are relatively homogeneous. When we analyse the standard error calculation of the two methods, the significance test under the bootstrapping method only considers the distribution of the estimators of the SDF coefficients $\{se(\hat{\beta}_{SFD}^1), se(\hat{\beta}_{SFD}^2), \dots, se(\hat{\beta}_{SFD}^n)\}$, whereas that under the simple resampling method considers the distribution of their standard errors $\{se(\hat{\beta}_{SFD}^1), se(\hat{\beta}_{SFD}^2), \dots, se(\hat{\beta}_{SFD}^n)\}$. Basically, it is as if in the simple resampling method, the individual significance of each estimate of $\hat{\beta}_{SFD}^i$ is taken into account through the standard errors.

To show this, let us take a simple example. We will estimate the effect of electricity on working time along two variables, working time in the market and domestic working time for adult men. We are considering 1000 iterations.

Figure 1.F1 shows for the two variables: working time on the market (sub-figure 1.F1a) and domestic working time (sub-figure 1.F1b), SDF coefficients and standard errors of the variable “Electricity” of the first 50 iterations. Figure Method2 is presented for the 1000 iterations. For each of the variables, we present the four estimates, using both rounds and both clustering methods. In total, we have 4000 estimates for each variable, which we call “All”, which are presented in Figure 1.F3. Looking at the previous figures, it is obvious that electricity increases the working time of adult men when it does not have a significant effect on domestic working time. Indeed, concerning the effect on market working time, 3961 out of 4000

coefficients (i.e. 99.03%) are significant at the 5% risk of error, whereas concerning the effect on domestic working time, only 14 out of 4000 coefficients (i.e. 0.35%) are significant. Figure 1.F4 outlines the distribution of each of the 4 types of estimates and for their whole (“All”). Figure 1.F5 outlines the estimates with our simple resampling approach and the bootstrapping approach. The estimates are the same except for standard errors. The values of standard errors by the bootstrapping approach are lower than those of the simple resampling approach. Both approaches show that electricity has a significant effect on the working time of adult men (sub-figure 1.F5a). Access to electricity leads to an increase of approximately 5.548 hours (“All”) per week jobs related. However, with regard to domestic working time (sub-figure 1.F5b), the two approaches lead to divergent results. According to the bootstrap approach, electricity has a significant positive effect regardless of the round or clustering process (an increase of 0.171 hours (“All”)); then the simple resampling approach presents non-significant effects. We have previously pointed out that only 0.35% of the estimated 4000 coefficients are significant, compared to 99.65% that are insignificant. We can thus conclude that non-significant effect is present. Thus, we can underline that the simple resampling approach seems more realistic and efficient, as it takes into account the individual standard error of each estimate of $\hat{\beta}_{SFD}^i$ to estimate the standard error of $\hat{\beta}_{SFD}^m$.

Subsequently, we will present our results using the simple resampling approach¹⁷. And very often instead of separating the analysis with the 1000 iterations of the 4 different estimates, we work to facilitate the reading and minimize the number of tables by presenting a single estimate based on the 4000 iterations (“All”).¹⁸

- *Adult analysis*

In this section, we discuss an analysis of adults (aged 18 or above). The results of the effects of electricity are reported in Table 1.F11. In addition to a gender analysis, we split the analysis by age group. Panel *A* presents the results for all adults, Panel *B* for those aged 18 to 35, and Panel *C* for those over 35 years of age. In each panel, we calibrate the results for all individuals in that panel (“All”), then

¹⁷Graphs on the distribution of coefficients are available upon request from the authors.

¹⁸Detailed tables are available upon request from the authors.

by gender, with “Male” for men and “Female” for women. The estimates are based on 4000 iterations.

Observing the results for all adults (Panel *A*), we note that electricity leads to an increase in working time of about 5 hours on average per week, and an increase in the production time of domestic services by about 1 hour. It also leads to a decrease in leisure time by an average of 2 hours. However, there is no significant effect on domestic production time, particularly the production time of domestic goods. Gender analysis shows differences only in leisure time, production of domestic goods, and domestic services. For men, electrification leads to a decrease in leisure time (5 hours) and an increase in the time spent on the production of goods (1.7 hours), while there are no significant effects for women. We also observe that the production time of domestic services increases by about 2.56 hours.

When looking at adults aged 18-35 (Panel *B*), it should be noted that electricity does not cause a substantial change in their time allocation. The effect on market working time appears positive but not significant. Comparing the results for men and women, electrification leads to an increase in the production time of domestic services for women but not for men.

For adults over the age of 35 (Panel *C*), access to electricity increases working time by about 6 hours. However, there are no significant effects on the time spent on other activities (domestic work, leisure, goods, and services). The difference between men and women lies in the time required for the production of goods and domestic services. There is an increase in the production time of domestic goods for men (2 hours), while for women, the production time of domestic services increases by about 1.18 hours.

One explanation for these results is that electrification also leads to economic burdens and domestic activities (maintenance of the house, appliance tools and electricity bills). The economic burdens are borne by the oldest people in the household (over 35 years of age), which is due to an increase in working time in the labour market. And, as the youngest often take care of domestic activities, they no longer have time for leisure. In the end, these young people are not gaining the effects of electricity as they should be.

The analysis suggests that access to electricity has different effects by gender and

age group. It has a significant effect on the working time of older adults, but not on younger adults in the household. There is no significant effect on domestic working time, and the negative effect on leisure time is not robust. Our results indicate a significant increase of 1 to 2.6 hours in the production time of domestic services for adult women, and an increase of about 2 hours in the production time of goods for men. These results do not support our assumptions for adults; the only one verified is that concerning working time.

In terms of adult well-being, we can conclude that electricity affects the well-being of older adults in the household through working time. The effects, however, are not robust, as electricity does not lead to the expected positive effects. Furthermore, there has been no improvement in the well-being of younger adults in the household (aged 18-35).

- *Analysis of Children*

In this section, we focus on the analysis of the effects of access to electricity on children. We first present the effects on the allocation of children's time and then the effects on education.

The results of the effects of electricity on time allocation are reported in Table 1.F12. A person is considered a child when he or she is under the age of 18. As before, in addition to a gender analysis, we split the analysis by age group. Panel *A* presents the results for all children, Panel *B* for those aged 5 to 13, Panel *C* for those between the ages of 14 and 17. In each panel, we calibrate the results for all individuals on this panel ("All"), then by gender, "Male" for boys and "Female" for girls.

For children aged 5-13, we do not have information on their level of education or working time in the labor market. Therefore, for working time, we consider it to be zero in order to calculate leisure time. While we do have data on working time in the labor market for those aged 14-17, our SFD approach does not allow us to obtain robust results for this age group. The SFD approach is effective under certain conditions, including: (i) geographically dense data to facilitate neighbor identification, and (ii) data that is sufficiently informative; otherwise, the difference procedure between nearby observations significantly reduces the number of obser-

ventions.¹⁹ Unfortunately, these conditions are not fully met in the study of working time for children aged 14-17. It should be noted that due to the random distribution of individuals in space, it is very difficult to identify two neighboring children who are working. In practice, even when we force estimates, the results are not reliable. We then focus on the other time variables.

If we consider the results for all children (Panel *A*), we see that electricity leads to a decrease in domestic working time of 2.2 hours, and especially the production time of domestic goods (1.52 hours). There is a positive effect on leisure time but no effect on the production time of domestic services. Gender analysis shows the same results, but the magnitude is greater for girls, with the exception of the effect on leisure time that is not significant.

When looking at children aged 5-13 (Panel *B*), we see the same effects as before and with greater magnitudes for girls. Electrification leads to a decrease in domestic production time, particularly in the production of domestic goods, and an increase in leisure time, but no effect on the production time of domestic services.

For children aged 14-17 (Panel *C*), we obtain the same signs as in Panels *A* and *B*, except for the production time of domestic services. However, none of the effects are significant, with the exception of the domestic working time for all children in this age group, for whom there is a negative and significant effect. In other words, access to electricity can reduce domestic working time. However, the effect is no longer significant when we split the analysis by gender. For this age group, it can be concluded that electricity has no effect on the allocation of their time. Indeed, this result suggests that the argument of increased domestic tasks, which we previously proposed for young adults aged 18-35, still holds here.

We further analyze how access to electricity affects education. In particular, we ask ourselves whether electricity improves children's performance in school. Indeed, we assume that the lighting problem can lead to poor performance in school, resulting in low levels of human capital and delays in education. In other words, education delays must be reduced for children with access to electricity compared to those without access. Our "education-delay" variable is obtained by calculating the

¹⁹For example, in estimating the working time of household heads, we used two estimation methods: the classical panel method used more than 3300 observations for men (Table 1.F7) compared to just 1900 for the SFD method (Table 1.F5), and more than 800 observations for women (Table 1.F8) compared to just 300 for the SFD approach (Table 1.F6).

difference between the child's current level of education and the level of education the child should have at his or her age. We estimate the level of education a child should have at a given age by the median level of education of children of that age in the population. The level of education is expressed in the number of years of study. The education delay variable is expressed in number of years and is limited to zero so that the delay in education level is not negative. It then takes the value 0 when the child is ahead of his/her level of education. As we seek to capture only the effect on the delay. In addition, the study is limited to children aged 14-17 due to data limitations.

The results of the effect of access to electricity on the delay in education levels are shown in Table 1.F13. This table presents the results of 1000 iterations for each round (R1 and R2) and following the clustering process ("Lat WE", "Long SN"). While we expect a negative sign, most of the coefficients are positive but not significant. Out of the estimated 15 coefficients, only one is significant. We conclude that access to electricity does not reduce the delay in education.

We conclude that electrification leads to an improvement in the well-being of children, especially those aged 5-13.

- *Analysis of labour market participation*

Next, we will look at whether access to electricity is associated with a high probability of participation in the labour market. We build a binary variable that takes 1 if the individual works at least 1 hour on the labour market, and 0 if not. The analysis is carried out for individuals aged 14 and over as the data on working time in the labour market is available for this group of population.

The results are displayed in the 1.F14. In addition to presenting gender analysis for all individuals (Panel A), we also focus on household heads (Panel B), adults (Panel C) and children (Panel D). As the dependent variable is binary, we do not apply SFD method. We use linear probability models (Column LPM), and Probit and Logit estimations. For these latter models, we simply present coefficients but not odds ratios or marginal effects. Indeed, we are less interested in causality. We are particularly interested in analyzing the links between variables. Hence, we avoid interpreting the variables. However, to take into account spatial autocorrelation and heteroscedasticity between neighbouring groups of individuals, we make an estimate

with robust standard errors grouped by groups of neighbors (“Lat WE” or “Long SN,” see the line “Cluster type”).

The results for all individuals (Panel *A*) show that electrification is associated with a high probability of participation in the labour market. This relationship is particularly verified on men, but not in women. For household heads (Panel *B*) and adults (Panel *C*), the same relationship is obtained, especially among men. Nevertheless, it is not verified for women. For children (Panel *D*), electrification reduces their likelihood of participation in the labour market, regardless of gender.

This analysis suggests that access to electricity is associated with a high probability of participation to labor market for men, but not for women. On the other hand, for children, access to electricity is associated with a low probability of participation in the labour market. This new evidence does not refute the idea that electricity improves the well-being of individuals. On the contrary, it supports.

1.8.4 Robustness by changing neighbors: rotation

Some of our results can be subject to criticism. To enhance robustness of our results for adults and children, we perform a resampling approach. Only 4 forms of regressions were presented for households, heads of households, and inequalities within households. These regressions are based on two types of neighbors: neighbors to the east or west, otherwise zero degree (0°) neighbors following the “Lat WE” clustering process (see Subfigures 1.D3a and 1.D4a); and neighbors to the north or south, otherwise ninety degree (90°) neighbors, following the “Long SN” clustering process (see Subfigures 1.D3b and 1.D4b). Nevertheless, individuals or households could have neighbors at 45° , 60° or 135° . Several neighbor configurations are therefore possible. We will then perform neighbor changes to be able to make the results more robust. The approach is similar to the simple resampling approach we used earlier. Except that here, it consists in changing neighbors with respect to a given angled. We use the same “average” estimator that we used with the simple resampling approach.

In terms of application, the approach is quite simple. It consists of choosing units of interest (e.g. a household), and the algorithm assigns one or more neighbors to it in a band defined at a given angle. This angle rotation allows you to know if the coefficients are stable by changing neighbors and in order to have an average

estimator.

For example, for an unit i , one wants to define its neighbors with a band rotation of 45° . To do this, we simply return the map of Rwanda of 45 degrees and then we select horizontally (west-east) the neighbors in the selected latitude band. The process is done in the same way to select the neighbors vertically (south-north). These are 135° neighbors ($45^\circ + 90^\circ$). The rotation on the map of Rwanda is done using the geospatial coordinates of the different households. Mathematically, this is a combination of translation and rotation operations. First, we translate the coordinates into a new reference frame whose origin is the center of gravity of Rwanda. Then, we carry out the rotation of defined angle around this center of gravity to obtain new coordinates. We then carry out a translation of these coordinates in the initial reference frame. We obtain then the new coordinates with rotation of the defined angle.

The mathematical equation is the rotation of a point is given by:

$$\begin{bmatrix} long'_j \\ lat'_j \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix} \times \begin{bmatrix} long_j - long_G \\ lat_j - lat_G \end{bmatrix} + \begin{bmatrix} long_G \\ lat_G \end{bmatrix} \quad (1.20)$$

Where G is the barycenter with coordinates $(long_G, lat_G)$ in a reference frame whose abscissa represents the longitude and the ordinate represents the latitude, θ is the angle of rotation (in degrees), j is the unit of interest with coordinates $(long_j, lat_j)$, and $(long'_j, lat'_j)$ are the new coordinates of unit j after rotation by angle θ . The barycenter G is obtained by calculating the barycenter of the geographic coordinates of all households in rounds 1 and 2. Figure 1.F6 shows the results for different angles of rotation. Figure 1.F6a displays the spatial distribution of individuals, the barycenter G of the points, and the extreme units A , B , C , and D used to define the bands. This figure also shows the spatial distribution of households in Rwanda in a two-dimensional plane without incorporating a satellite map in the background. Figures 1.F6b, 1.F6c, and 1.F6d show the rotations by 45° , 90° , and 135° around the barycenter G , respectively.

In this study, we perform a robustness with changes of neighbors by rotation of angle from 1 to 180 degrees.

- *Analysis of the average time allocation in a household*

Further, we discuss the average time results for each type of household activity, and also analyze the type of household head.

T

To show an example of the results of the estimates with change of neighbors by angle rotation, Figure 1.F7 presents the results at the household level. For each variable, we can see the 180 estimates corresponding to the 180 angles for each type of clustering process (“Lat WE” or “Long SN”) and for each phase. Thus, for each variable, we have 720 (180×4) estimates. To obtain an “average” estimate, we use the simple resampling estimator, with $n = 720$. This is the estimate that we will present in the remainder of the analysis.²⁰

Household results are presented in Panel A of Table 1.F15. For all households (line “All”) as well as households for which household heads are men (line “Male”), and households for which household heads are women (line “Femal”), the results, including signs and magnitude of coefficients, are consistent with the initial results of the tables 1.F1, 1.F2, 1.F3 respectively. Our results remain highly robust to the change of neighbors.

- *Analysis of the average time inequality in a household*

The results of inequalities between the head of household and his spouse are shown in Figure 1.F8 and the “average” estimates reported in Table 1.F16. This table presents the results of 180 degrees for each round (R1 and R2) and following the clustering process (“Lat WE”, “Long SN”), as well as for the entire set (Column “All”).

Panel A captures to inequalities in time allocation and Panel B income inequality. The results are consistent with our initial conclusions except for the unequal working time. In addition, the results suggest that inequalities in domestic production time (total, goods, or services) and leisure are not explained by access to electricity. They also point out that income inequality is also explained by access to electricity.

In the initial working time results, we showed that access to electricity can lead to increased inequalities in working time in the labor market. Furthermore, it is very likely that income inequality is partly explained by inequalities in market working

²⁰All figures showing spot estimates with change of neighbors for angle rotation are available from the authors upon request.

time. However, the robustness exercise does not fully support this view. Although the different electricity coefficients in columns “R1 - Lat WE”, “R1 - Long SN”, “R1 - Lat WE”, “R1 - Long SN” and “All” are positive for working time in the market, they are not significant. We then explore the 720 estimates presented in Figure 1.F9. It can be noted that sometimes the coefficients appear significant and sometimes not. Of the 720 estimated coefficients, 244 are significant at the 5% threshold, or 33.88% of the coefficients, and 322 are significant at the 10% threshold, or 44.72% of the coefficients. Hence, access to electricity can lead to increased inequalities in working time in the labor market, although this result is not very robust.

To conclude this study, we refer to Table 1.F17, which provides a summary (Column “Verified?”) indicating whether our hypotheses (Column “Hyp.”) are consistent with the results (Column “Est.”) or not. Several results are consistent with the assumptions, with the exception of the educational performance of children, the working time of female heads of households, and both domestic working time and adult leisure time.

1.9 Conclusion

Access to energy, particularly electricity, can have several impacts at the macro and micro levels. This study focuses on the microeconomic impact of access to electricity on welfare, through the distribution of time within households. We also document the effects on intra-household time, on income inequality, on labor market participation, and school performance. In our analysis, we distinguish the effect by gender and age group.

Based on the work of Gronau (1977), we develop a simple theoretical model where access to electricity is assimilated to a technological shock, leading to an increase in the time allocation of individuals. Individuals must allocate the additional time to different activities in the household. The activities are: market work (paid work), domestic work (total) composed of the production of domestic goods and the production of domestic services, and finally leisure. An individual can either be market-good intensive, i.e. preferring the market products he or she earns by offering his or her time in the labor market; or leisure intensive, i.e. spending time on leisure and producing the household goods needed for these needs.

The implications of the model show that access to electricity can lead to an increase in leisure time for leisure-intensive individuals (e.g., children) and to an increase in domestic time for other individuals. For individuals who are market-good intensive, access to electricity leads to increases in both leisure and work time. However, the increase in market work time depends primarily on the flexibility of the labor market. In a flexible market, individuals can increase working time easily, whereas this is more complicated in a labor-rigid market. Additionally, individuals experience a reduction in the constraint of domestic time, as access to electricity decreases domestic time through a reduction in the use of handicraft tools, which are replaced by household appliances.

We test the implications of the model using Rwanda labor market survey data over two rounds of surveys, including round 1 in February 2018 and round 2 in August 2018. These surveys are designed to analyze the dynamics of the labor force in the country. However, due to some changes in the survey structure, we treat the two rounds separately.

We use the Spatial First Difference (SFD) method developed by [Druckenmiller and Hsiang \(2018\)](#) to empirically estimate the effect of electricity access on time allocation. In addition, it is used to analyze whether access to electricity also leads to inequalities in time allocations and income inequalities within households. Moreover, SFD method is robust to unobservable heterogeneities common to neighboring units (households or individuals).

We show that at the overall household level, access to electricity has a positive impact on working time. It loosens the constraints of domestic production time (total, goods, and services) but has no effect on household leisure time. Access to electricity is a factor contributing to household well-being, with more robust effects in male-led households, and larger effects when the head of household is a woman.

The analysis of households shows that access to electricity produces an increase in working time, and a reduction in leisure time, but no robust effect on domestic working hours (total, goods or services). And, the effect is more important for heads of household who are men.

In terms of inequalities in the distribution of time, access to electricity can lead to an increase in inequalities in working time in the market, but this result is not

robust. It does not explain the inequalities in domestic production time (total, goods, or services). It also leads to income inequality between a head of household and his or her spouse.

At the adult level, access to electricity has a significant effect on the working time of older people (over 35 years), but not on young people in the household (between 18 and 35 years of age). There is no significant effect on domestic working time. The negative effect on leisure time is not robust. However, there has been a significant increase in the hours of production of domestic services among adult women, and an increase in the production time of men's goods.

At the children's level, electrification leads to a decrease in domestic working time, particularly the production time of domestic goods. There is a positive effect on leisure time but no effect on the production time of domestic services. Gender analysis shows the same results, but the magnitude is greater for girls, with the exception of the effect on leisure time that is not significant for girls. The analysis by age group shows such results for children aged 5-13, and for girls, a positive effect on leisure time. For children aged 14-17, we find that electricity has no effect on the allocation of their time and poor performance in school.

With regard to participation in the labour market, it is noted that access to electricity is associated with a high probability of participation of men, but not of women. For children, access to electricity is associated with a lower likelihood of participation in the labour market.

Our results suggest that electricity has a positive impact on household well-being, but at the individual level the effects on well-being are not sufficiently felt for adults between the ages of 18 and 35 and children aged 13-17. Access to electricity leads to income inequalities between the head of household and his spouse, partly through the inequalities in working time in the market that it can create.

The study has several limitations. First, the short-term nature of the Rwanda labor market data limits the ability to capture long-term impacts of electrification. Additionally, the assumption that younger children (aged 5-13) do not engage in informal labor may overlook their contributions to domestic or family activities, skewing time allocation analysis. Data limitations on adolescents aged 14-17, particularly regarding working hours, also present gaps in understanding how electrifi-

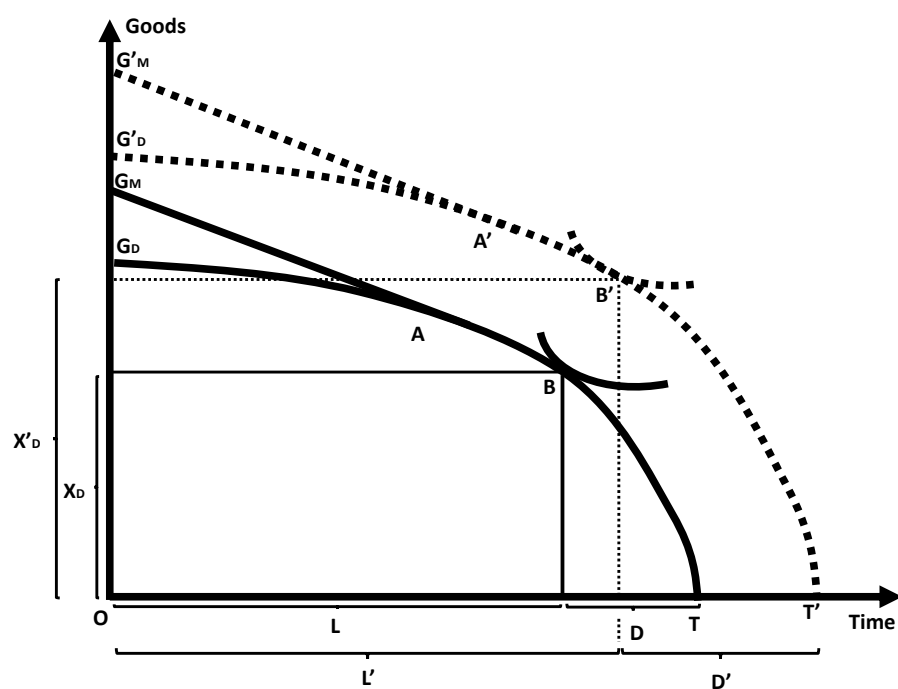
cation affects this group. Future research could extend the timeframe and provide a more nuanced analysis of labor contributions across all age groups.

Another key limitation is the potential selection bias in determining which households receive electricity access. Electrification programs often target specific regions or communities, which may influence the observed effects. Moreover, while the study touches on the educational impacts of electricity access, the use of overall education levels as a measure may be too aggregated. A more detailed analysis of school participation rates and educational quality would provide a better understanding of these impacts. Further studies should focus on how these dynamics unfold over time and across different educational outcomes.

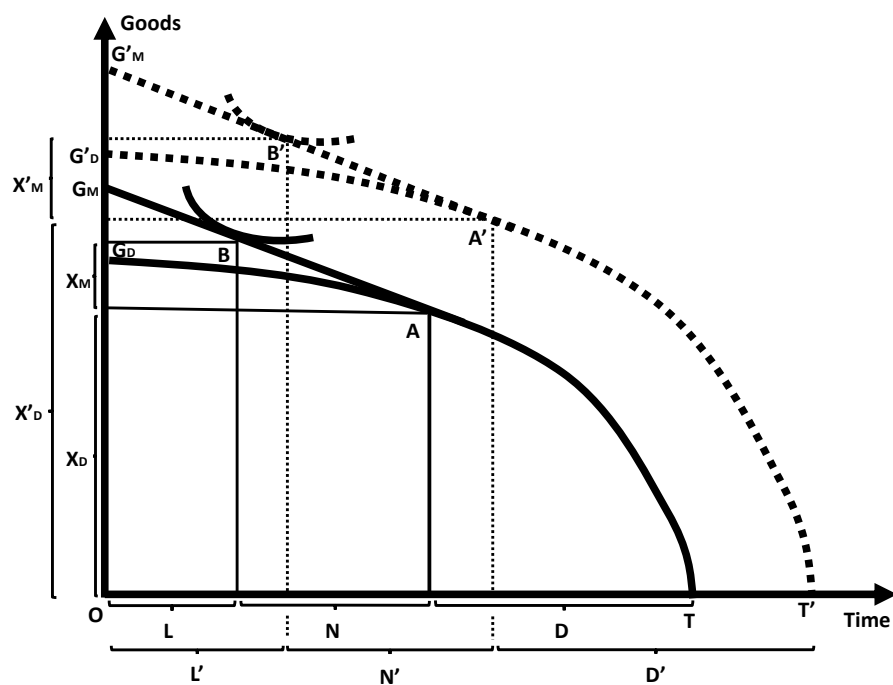
Lastly, while we show that electricity access improves labor market participation and household welfare, we do not explore how local economic, cultural, or infrastructural contexts influence these outcomes. Barriers to technology adoption, such as the affordability of appliances and digital literacy, may limit the expected productivity gains. Future research should investigate these contextual factors, especially in understanding the gender-specific effects on labor market participation and income inequality within households.

APPENDIX

A Theoretical framework

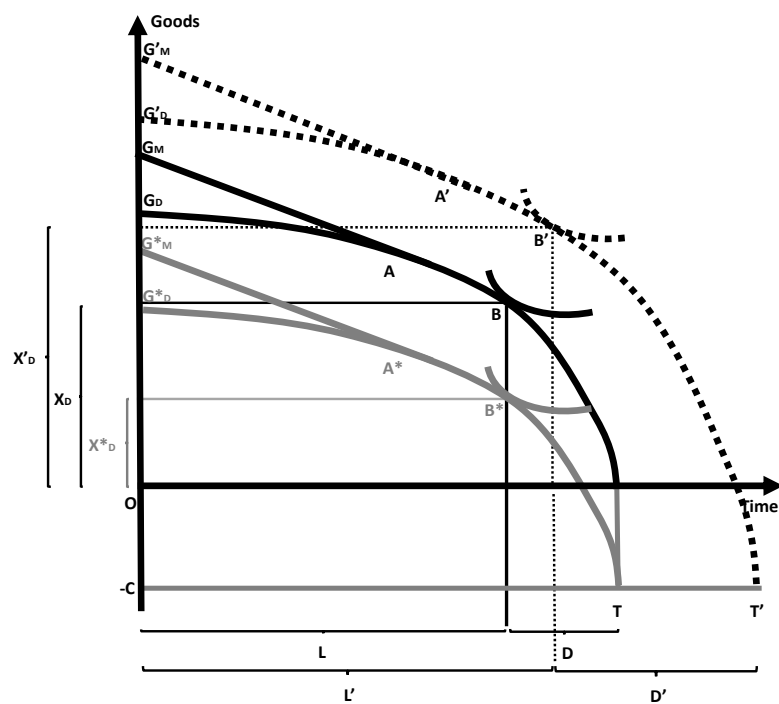


(a) Strong preference for leisure

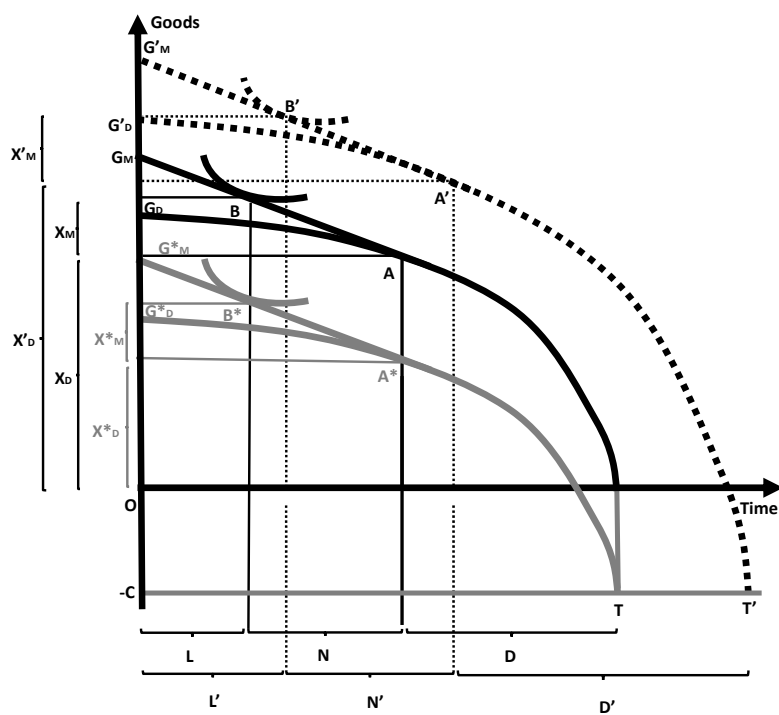


(b) Strong preference for goods

Figure 1.A1: Time allocation



(a) Strong preference for leisure



(b) Strong preference for goods

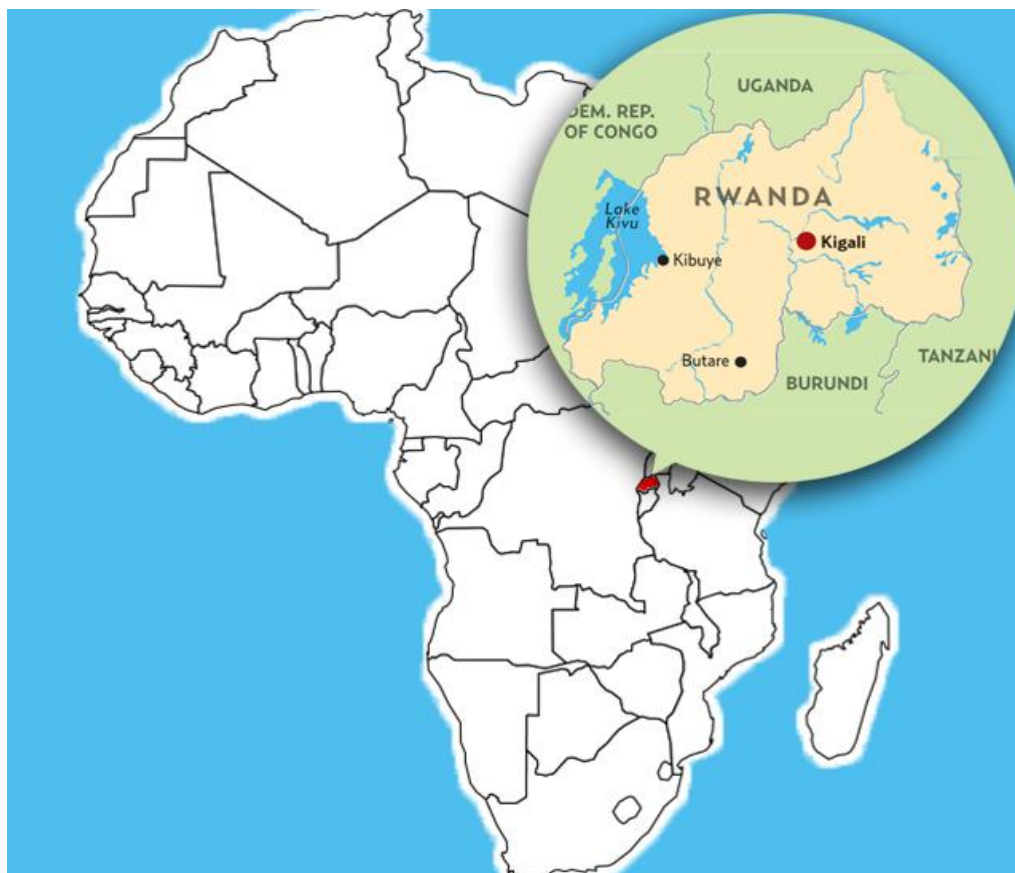
Figure 1.A2: Time allocation with electricity and cost

B Theoretical assumptions of the model and welfare

Table 1.B1: Expected effects of electricity

		Time allocation			
		Labor market	Domestic/Home	Leisure	Education
Children	Girls	-	- or Null	+	+
	Boys	-	- or Null	+	+
Household head	Men	+	- or Null	+/-	
	Women	+	- or Null	+/-	
Adults	Men	+	-	+	
	Women	+	-	+	

C Data



Source: <https://greenhillsacademyblog.wordpress.com/>

Figure 1.C1: Rwanda



Source: <http://rwanda.canalblog.com/>

Figure 1.C2: Rwanda Cities

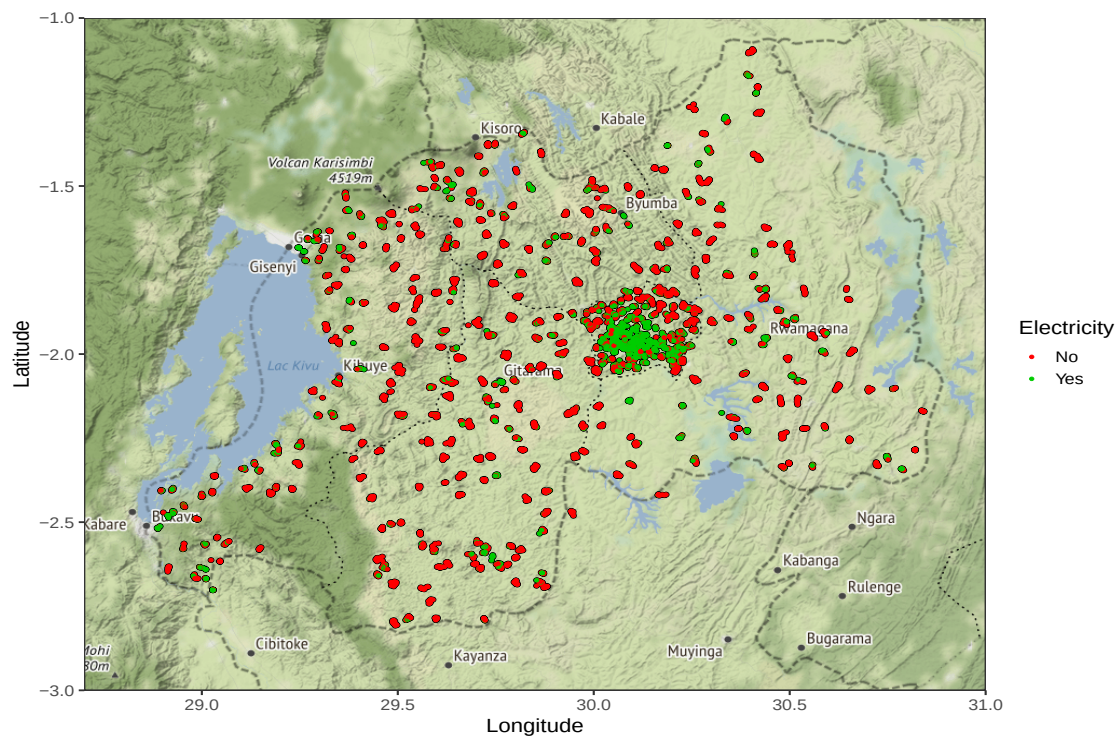


Source:

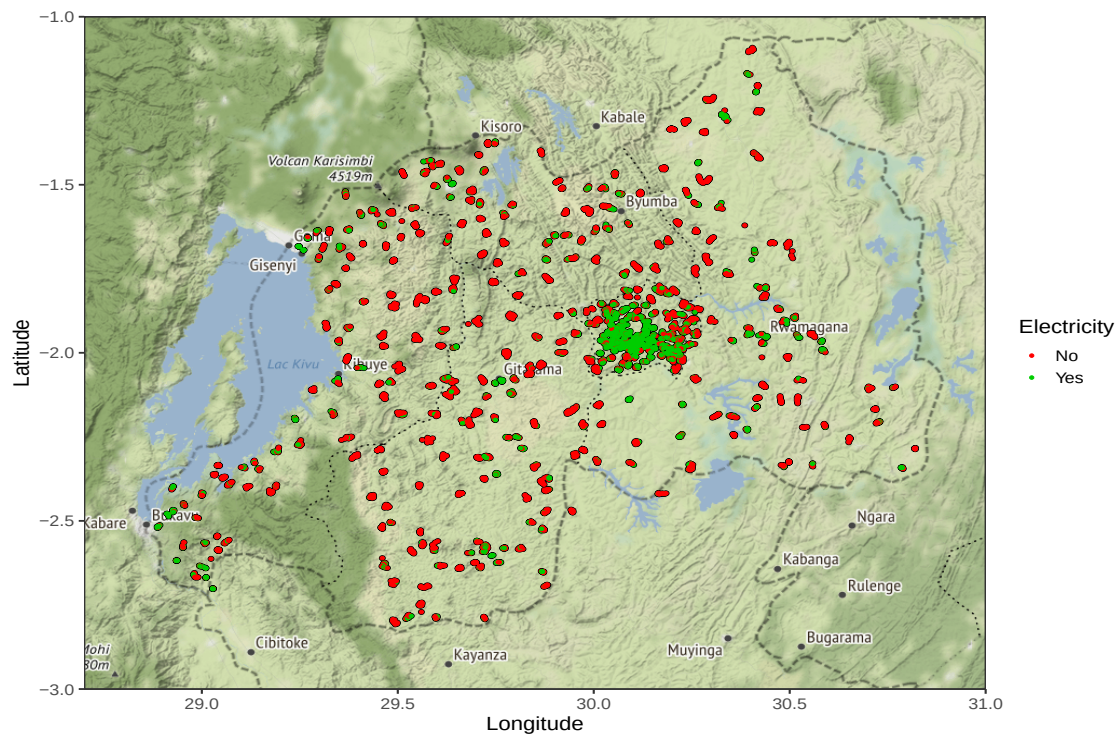
<http://www.ambarwanda-paris.fr/index.php/accueil-4/accueil-10/administration>

Figure 1.C3: Rwanda Districts

D Methodology



(a) Round 1

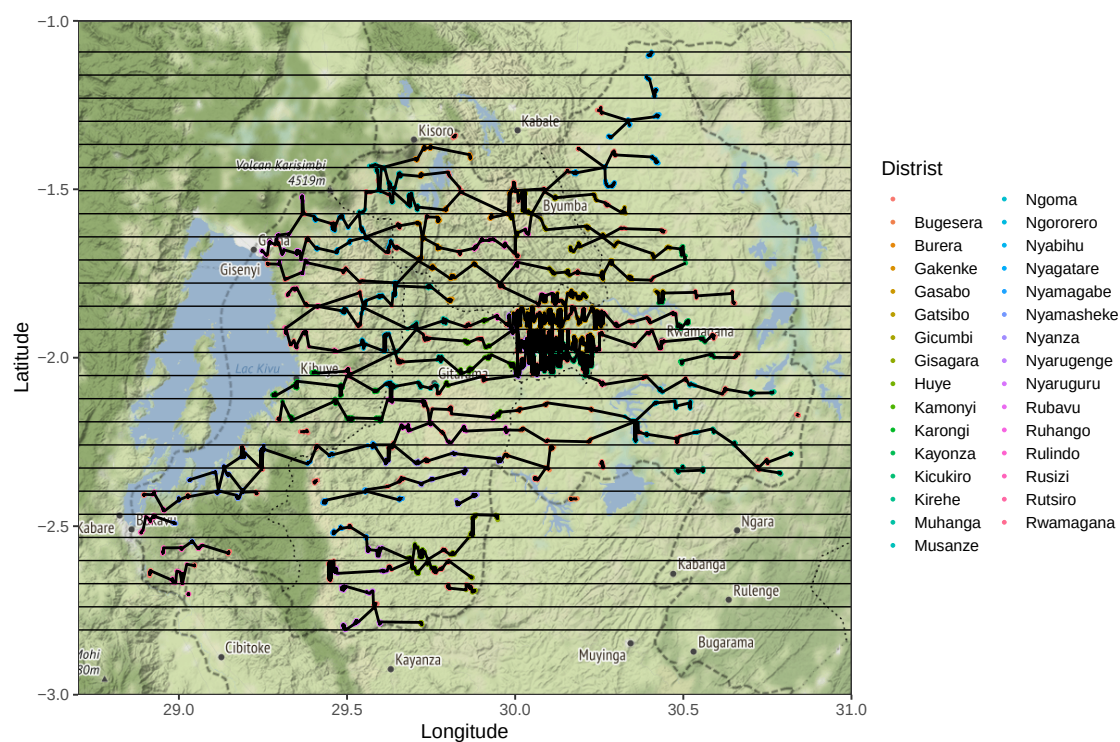


(b) Round 2

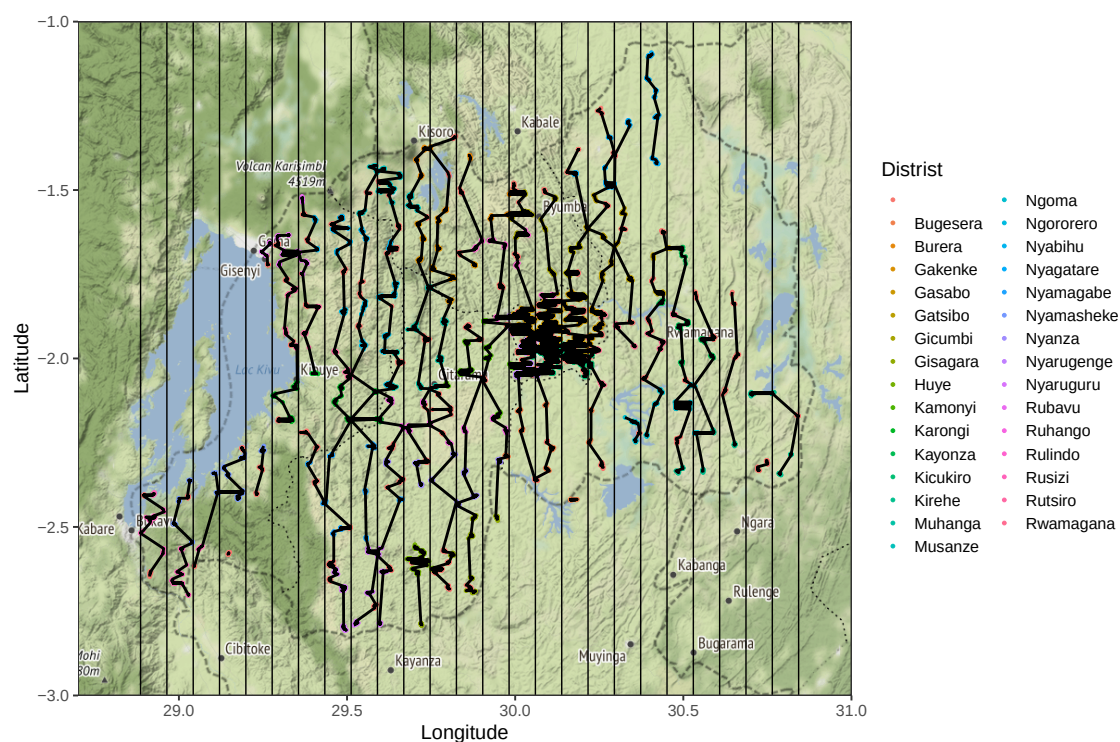
Figure 1.D1: Electricity access in Rwanda



Figure 1.D2: SFD design to Rwanda survey data

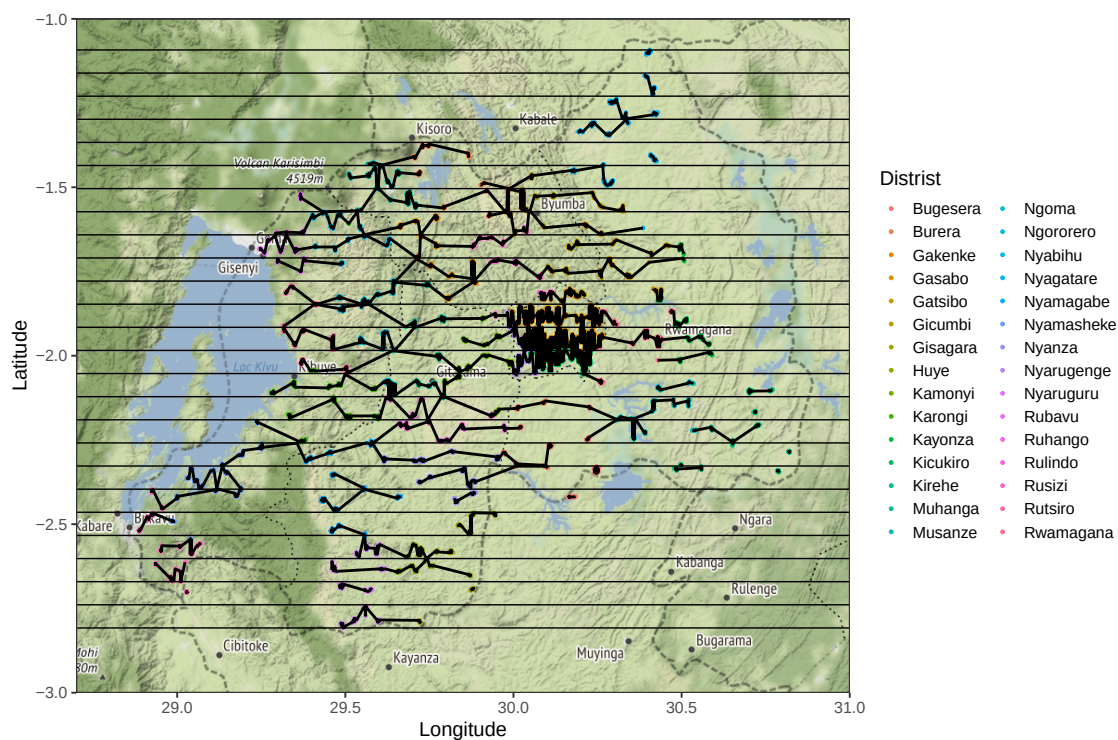


(a) Process of clustering in Latitude West-East

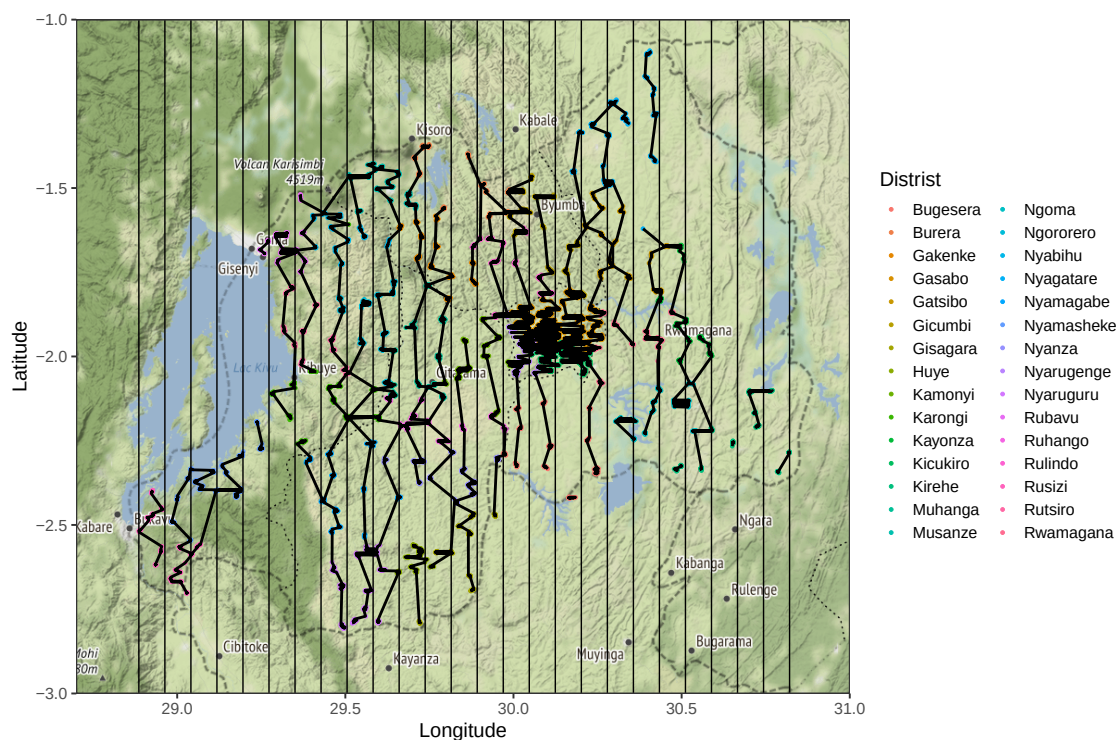


(b) Process of clustering in Longitude South-North

Figure 1.D3: Round 1: Process of clustering

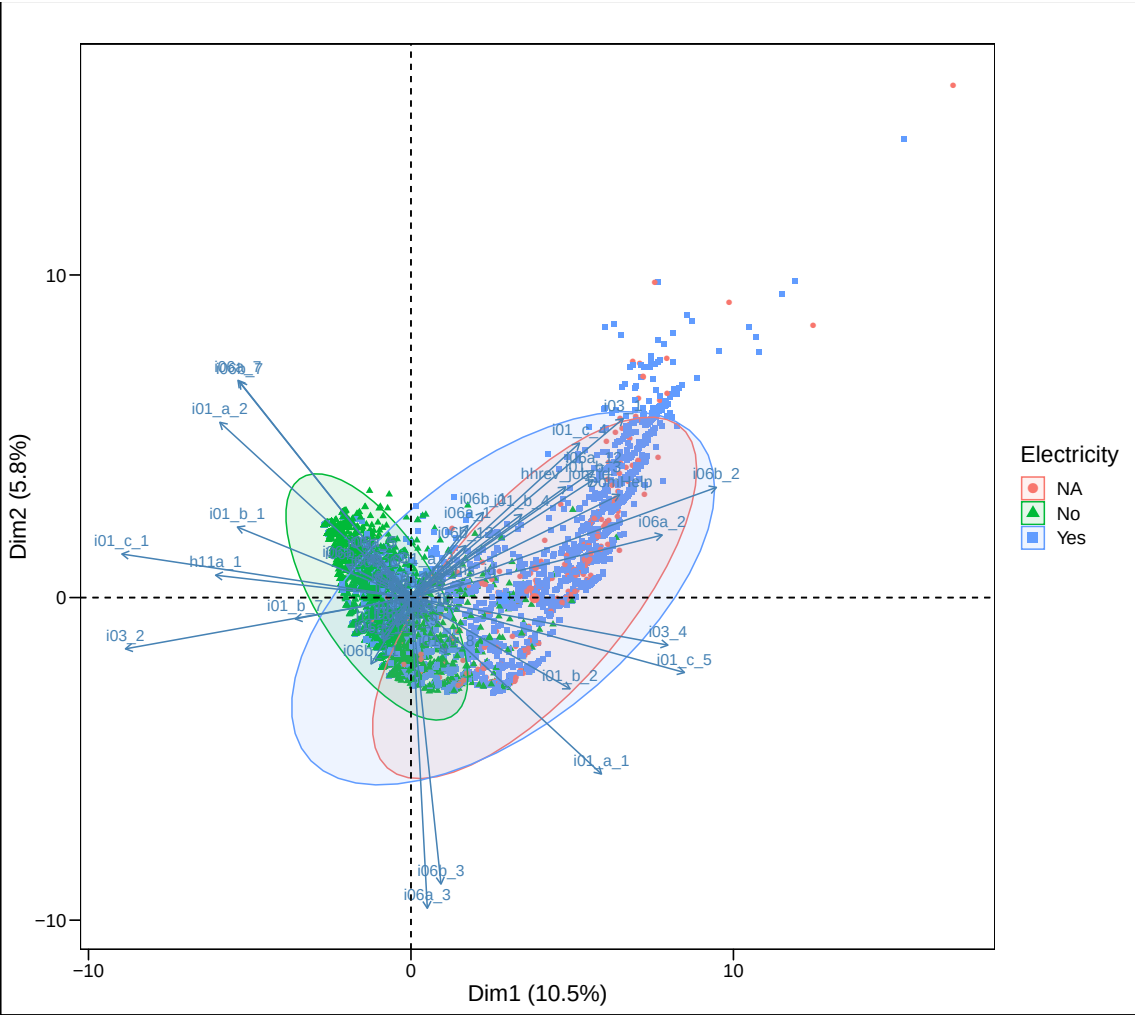


(a) Process of clustering in Latitude West-East

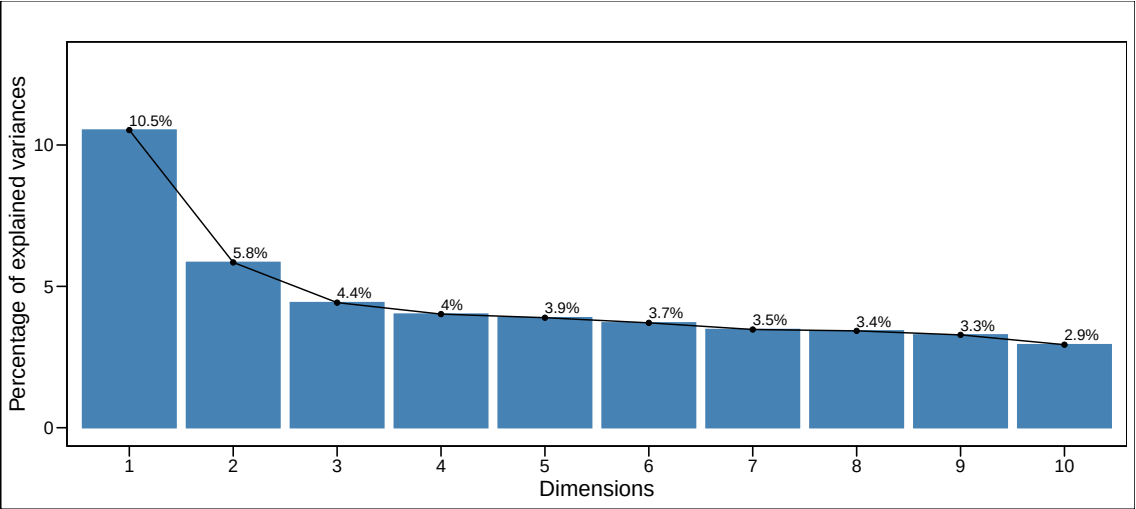


(b) Process of clustering in Longitude South-North

Figure 1.D4: Round 2: Process of clustering

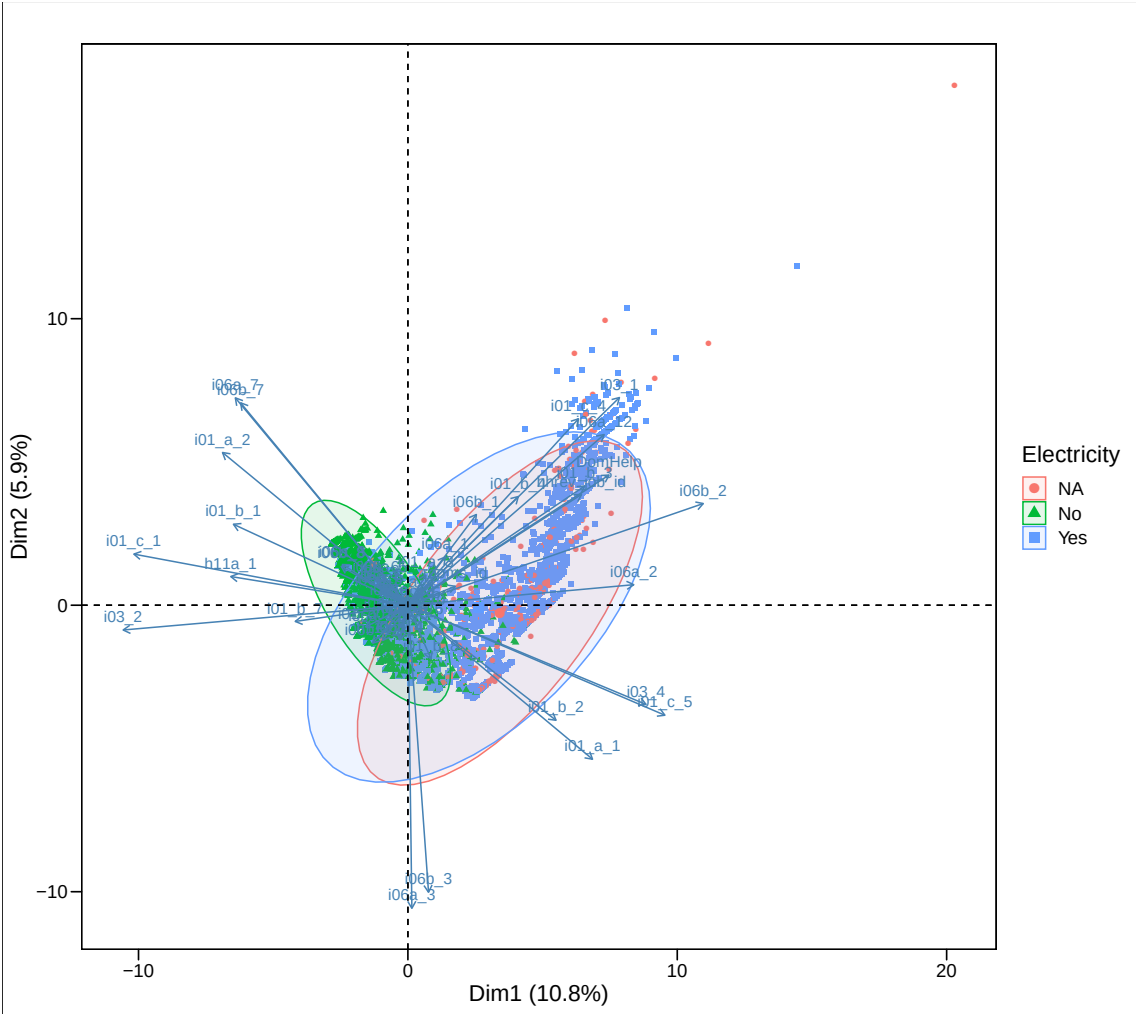


(a) Biplot of axes

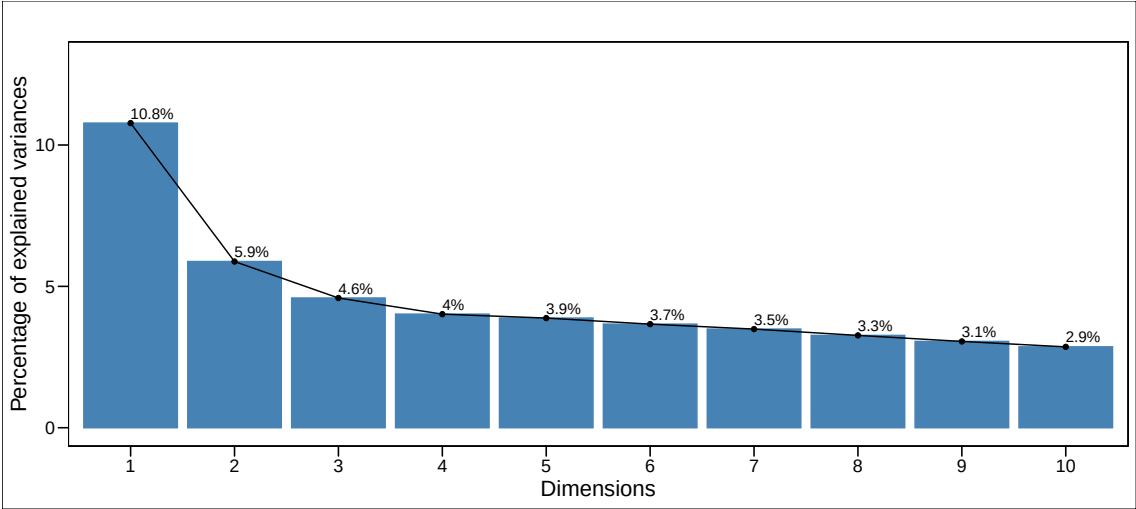


(b) Eigenvalues

Figure 1.D5: Round 1: Wealth indicator construction using PCA

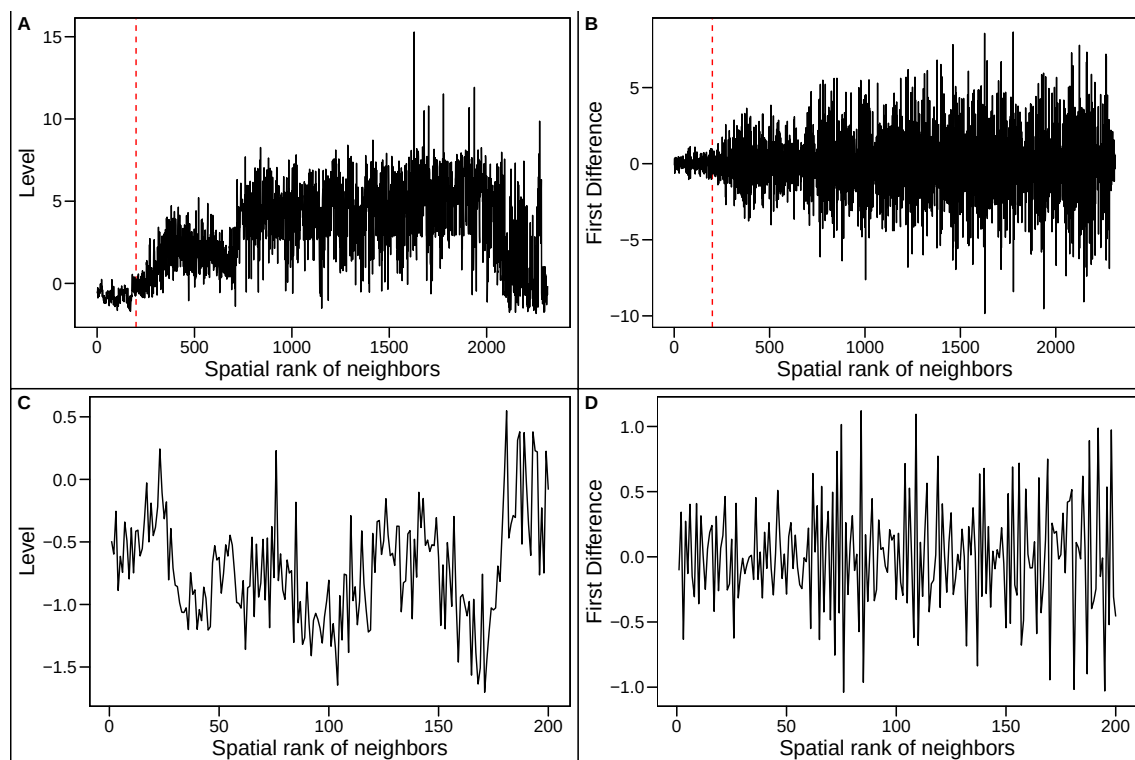


(a) Biplot of axes

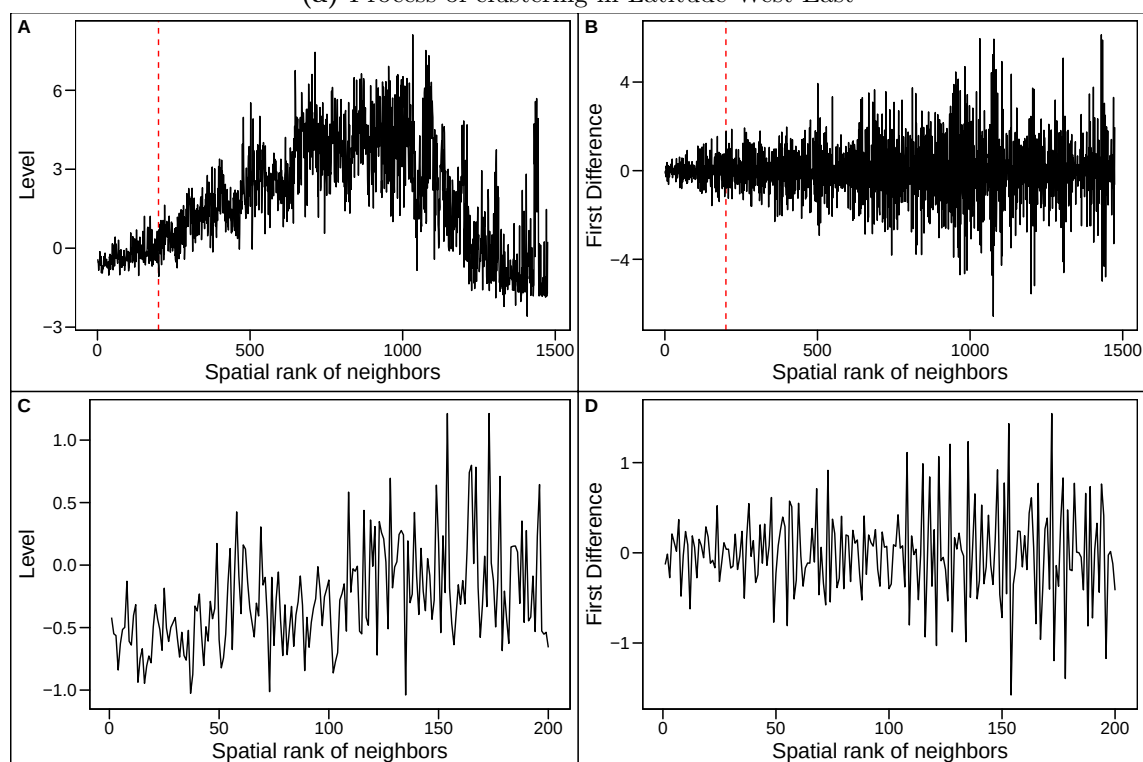


(b) Eigenvalues

Figure 1.D6: Round 2: Wealth indicator construction using PCA

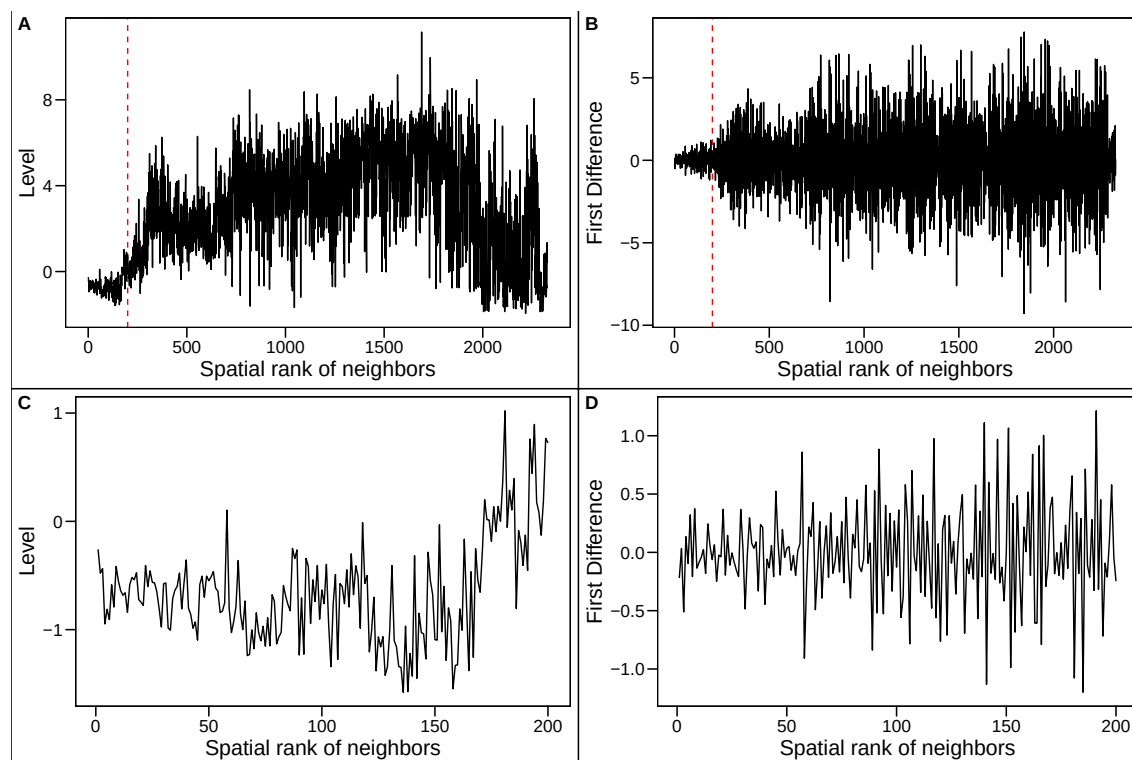


(a) Process of clustering in Latitude West-East

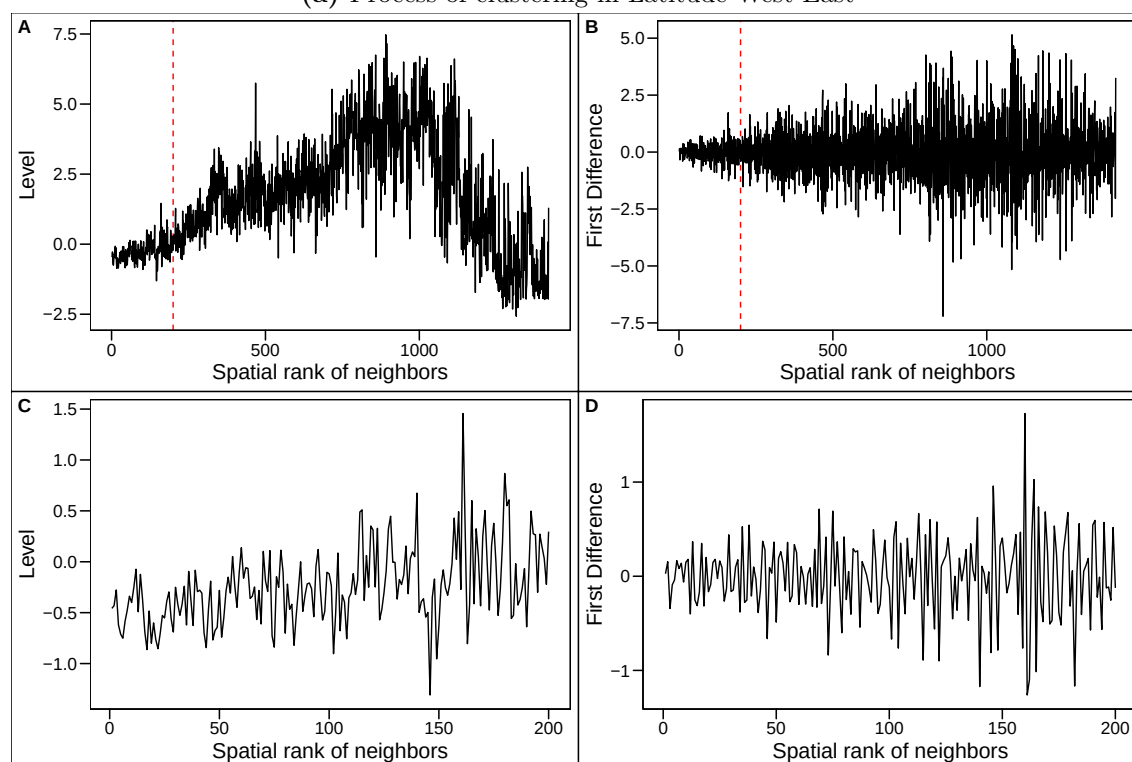


(b) Process of clustering in Longitude South-North

Figure 1.D7: Round 1: Level of wealth of neighboring households in Rwanda



(a) Process of clustering in Latitude West-East



(b) Process of clustering in Longitude South-North

Figure 1.D8: Round 2: Level of wealth of neighboring households in Rwanda

Table 1.D1: Result of clustering process

	(1) Round 1	(2) Round 2
Number of household	8469	8588
<i>Panel A: Clustering process in Latitude West-East</i>		
Cluster		
... Number of cluster	54	61
... Size of neighbouring households		
... ... Min	1	1
... ... Mean	425	415
... ... Median	149	132
... ... Max	2313	2328
... ... Std. Dev.	585	591
<i>Panel B: Clustering process in Longitude South-North</i>		
Cluster		
... Number of cluster	34	37
... Size of neighbouring households		
... ... Min	1	1
... ... Mean	345	341
... ... Median	189	189
... ... Max	1475	1420
... ... Std. Dev.	377	368

Table 1.D2: Test of means

Round	Clust. Process	Variable at Level			Variable at First Difference		
		Mean (H0: = 0)	T Student	N	Mean (H0: = 0)	T Student	N
Size of the household							
1	Lat WE	4.0374***	96.926	2313	-0.0019	-0.032	2312
1	Long SN	4.0537***	112.645	1475	-0.0013	-0.028	1474
2	Lat WE	4.0889***	96.187	2328	-0.0026	-0.044	2327
2	Long SN	4.1121***	117.098	1420	4,00E-04	0.009	1419
Household wealth indicator							
1	Lat WE	3.1454***	58.706	2313	-0.0011	-0.023	2312
1	Long SN	1.8051***	32.802	1475	-0.0042	-0.116	1474
2	Lat WE	2.9005***	56.355	2328	-5,00E-04	-0.01	2327
2	Long SN	1.6393***	31.073	1420	-0.0036	-0.103	1419
Number of rooms per capita							
1	Lat WE	0.6916***	84.084	2313	0	-0.003	2312
1	Long SN	0.6912***	86.674	1475	6,00E-04	0.059	1474
2	Lat WE	0.687***	84.201	2328	5,00E-04	0.04	2327
2	Long SN	0.6814***	89.977	1420	9,00E-04	0.089	1419
Domestic helper or servant							
1	Lat WE	0.1968***	25.1	2313	-2,00E-04	-0.024	2312
1	Long SN	0.1244***	22.778	1475	-1,00E-04	-0.016	1474
2	Lat WE	0.2***	25.706	2328	-1,00E-04	-0.014	2327
2	Long SN	0.1293***	23.505	1420	-3,00E-04	-0.044	1419
Number of children aged 13 and under							
1	Lat WE	1.2249***	50.996	2313	4,00E-04	0.013	2312
1	Long SN	1.3457***	61.025	1475	-4,00E-04	-0.015	1474
2	Lat WE	1.2682***	51.039	2328	-0.0015	-0.045	2327
2	Long SN	1.3865***	62.968	1420	0.0025	0.085	1419
Level of education of the head of household							
1	Lat WE	12.3002***	143.679	1815	-0.0183	-0.152	1504
1	Long SN	11.2817***	117.201	1450	-0.0024	-0.019	1395
2	Lat WE	12.3294***	141.275	1837	0.0101	0.081	1545
2	Long SN	11.326***	125.049	1401	-0.0531	-0.438	1354

E Descriptive analysis

Table 1.E1: Descriptive statistics

	Full sample			Sample without Electricity			Sample with Electricity			Test of difference	
	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Diff.	T Stud.
Round 1											
Labor market time	38.318	19.701	3034219	32.795	16.665	1856686	46.713	20.923	1108918	13.918***	36.484
Home time	13.981	14.389	9594948	15.435	14.379	6469480	11.025	14.061	3031549	-4.41***	-24.981
Time for goods	8.877	8.253	7125170	9.669	8.359	5374008	6.475	7.43	1720653	-3.193***	-24.265
Time for services	9.563	10.971	7412889	9.264	10.246	5170327	10.267	12.609	2169707	1.003***	6.311
Leisure time	129.758	28.335	9763799	129.778	27.938	6487767	130.147	29.024	3182114	0.369	1.077
Age	24.19	19.136	11287896	24.46	19.948	7520448	23.33	17.33	3673530	-1.129***	-5.251
HH size	5.333	2.024	11287896	5.201	1.953	7520448	5.716	2.029	3673530	0.515***	23.166
Nb. Children (-13)	2.077	1.447	11287896	2.135	1.45	7520448	2.011	1.419	3673530	-0.124***	-7.673
Education	11.195	4.799	6772232	10.428	5.003	4589560	12.821	3.842	2114466	2.393***	34.446
Education of Head	10.265	5.489	10622166	9.377	5.65	7473506	12.373	4.42	3080454	2.996***	46.397
Income	1.367	6.775	2656159	0.599	0.841	1672636	2.629	11.139	921332	2.029***	13.504
HH Income	2.315	11.019	7973656	0.965	1.255	5111432	4.756	18.228	2800032	3.791***	26.815
Rooms	2.562	0.97	11287896	2.419	0.858	7520448	2.882	1.091	3673530	0.463***	43.721
Nb. Children (14-17)	0.593	0.77	11287896	0.574	0.746	7520448	0.648	0.819	3673530	0.074***	8.503
Nb. Children (-17)	2.67	1.679	11287896	2.709	1.659	7520448	2.658	1.685	3673530	-0.051***	-2.694
Gender	0.519	0.5	11287896	0.524	0.499	7520448	0.514	0.5	3673530	-0.01*	-1.782
Rooms (pc)	0.544	0.313	11287896	0.533	0.315	7520448	0.545	0.248	3673530	0.012***	3.622
HH Income (pc)	0.456	1.982	7973656	0.196	0.262	5111432	0.866	3.044	2800032	0.67***	28.318
Domestic Help	0.015	0.121	11287896	0.002	0.049	7520448	0.041	0.198	3673530	0.039***	28.5
Round 2											
Labor market time	39.695	20.505	3310406	33.404	17.888	1870743	47.599	20.884	1355386	14.195***	37.418
Home time	15.018	15.319	9918643	16.679	15.416	6240595	12.289	14.855	3570552	-4.39***	-24.198
Time for goods	9.465	9.051	7328410	10.367	9.182	5220832	7.283	8.347	2069710	-3.084***	-22.499
Time for services	10.35	11.668	7690466	10.035	11.045	4978925	10.953	12.84	2629886	0.918***	5.71
Leisure time	128.878	28.954	10098549	129.207	28.636	6252557	128.754	29.388	3738496	-0.453	-1.342
Age	24.118	19.025	11667250	24.366	19.953	7250269	23.396	17.314	4309485	-0.97***	-4.701
HH size	5.337	2.042	11667250	5.196	1.962	7250269	5.682	2.046	4309485	0.485***	22.425
Nb. Children (-13)	2.073	1.455	11667250	2.148	1.461	7250269	1.998	1.42	4309485	-0.15***	-9.545
Education	11.228	4.762	6967968	10.349	5.01	4409605	12.752	3.821	2480670	2.403***	36.233
Education of Head	10.354	5.492	10883725	9.356	5.651	7202062	12.304	4.57	3603970	2.948***	47.43
Income	1.409	4.852	2852050	0.635	0.959	1653731	2.434	7.333	1120015	1.8***	17.772
HH Income	2.385	8.272	8518161	0.978	1.275	5093008	4.511	12.776	3346848	3.534***	34.99
Rooms	2.588	0.981	11667250	2.414	0.845	7250269	2.911	1.094	4309485	0.497***	48.454
Nb. Children (14-17)	0.58	0.761	11667250	0.565	0.734	7250269	0.62	0.808	4309485	0.055***	6.628
Nb. Children (-17)	2.653	1.666	11667250	2.713	1.655	7250269	2.618	1.649	4309485	-0.095***	-5.293
Gender	0.519	0.5	11667250	0.525	0.499	7250269	0.514	0.5	4309485	-0.012**	-2.162
Rooms (pc)	0.548	0.309	11667250	0.531	0.308	7250269	0.554	0.249	4309485	0.023***	7.437
HH Income (pc)	0.473	1.419	8518161	0.206	0.341	5093008	0.818	1.915	3346848	0.612***	39.772
Domestic Help	0.015	0.123	11667250	0.002	0.041	7250269	0.039	0.193	4309485	0.037***	28.008

Table 1.E2: Descriptive statistics for adults by gender

	Full sample			Sample without Electricity			Sample with Electricity			Test of difference	
	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Diff.	T Stud.
Mal											
Round 1											
Labor market time	41.93	20.125	1599921	36.832	17.86	958697	49.298	20.912	588647	12.467***	22.839
Home time	9.216	11.042	2775940	10.907	11.572	1772908	6.138	9.424	939546	-4.769***	-19.484
Time for goods	10.517	8.958	1572181	10.959	8.936	1216288	9.308	8.975	336262	-1.651***	-4.986
Time for services	6.833	6.51	1324246	6.71	6.44	895325	6.857	6.734	384521	0.148	0.659
Leisure time	122.132	26.08	2836282	122.479	25.428	1782556	122.146	27.06	990241	-0.332	-0.581
Age	37.147	15.619	2836380	38.548	16.512	1782556	34.942	13.845	990338	-3.606***	-10.501
Education	11.472	4.712	2612281	10.654	4.945	1755554	13.145	3.667	809977	2.491***	22.63
Income	1.738	8.729	1448774	0.758	1.078	893804	3.303	14.343	506969	2.545***	9.594
Round 2											
Labor market time	43.441	20.371	1782942	37.879	18.755	980810	50.116	20.295	735893	12.237***	23.359
Home time	9.496	12.101	2880115	11.326	12.837	1694691	6.782	10.501	1109743	-4.544***	-17.447
Time for goods	11.071	9.991	1580343	11.578	10.056	1152168	10.102	9.829	401610	-1.475***	-4.2
Time for services	7.455	7.925	1321509	7.393	7.878	792018	7.298	7.96	475370	-0.094	-0.365
Leisure time	121.243	26.836	2946274	122.1	26.69	1700199	120.683	26.906	1170393	-1.417**	-2.486
Age	36.874	15.418	2946373	38.367	16.436	1700199	34.985	13.779	1170493	-3.382***	-10.311
Education	11.538	4.682	2697463	10.596	4.968	1676420	13.073	3.668	968230	2.477***	23.686
Income	1.733	6.057	1594541	0.808	1.201	903518	2.902	9.134	629495	2.094***	12.26
Femal											
Round 1											
Labor market time	35.123	17.993	1275525	29.131	13.375	784182	44.463	20.115	475438	15.332***	29.823
Home time	22.738	16.625	3163878	24.006	16.252	2127518	20.363	17.18	1006063	-3.643***	-10.235
Time for goods	10.318	8.344	2168102	10.923	8.496	1688790	8.218	7.397	468434	-2.706***	-10.52
Time for services	17.541	12.36	2825770	16.812	11.293	1940686	19.418	14.387	856763	2.607***	9.124
Leisure time	116.364	26.375	3247706	115.503	25.832	2131304	117.913	27.214	1086105	2.41***	4.412
Age	38.316	16.317	3248965	40.001	16.831	2131304	34.839	14.519	1087363	-5.162***	-15.457
Education	10.619	5.475	3082360	9.717	5.618	2115895	12.639	4.511	945144	2.922***	24.931
Income	0.97	3.149	1112248	0.424	0.361	713819	1.918	4.956	384374	1.494***	14.688
Round 2											
Labor market time	36.62	19.387	1353123	29.437	14.824	763937	45.666	20.621	571231	16.229***	30.345
Home time	24.507	17.324	3277334	26.232	17.013	2058929	21.866	17.541	1186675	-4.366***	-12.259
Time for goods	11.021	9.152	2210541	11.662	9.356	1653263	9.193	8.244	546061	-2.469***	-9.175
Time for services	18.888	12.657	2962558	18.26	11.701	1901928	20.256	14.209	1033181	1.996***	7.146
Leisure time	115.712	27.047	3371951	115.026	26.737	2062607	116.663	27.404	1277613	1.637***	3.031
Age	38.094	16.33	3373516	40.022	17.001	2062607	34.806	14.463	1279179	-5.216***	-16.216
Education	10.665	5.427	3174710	9.621	5.609	2045923	12.601	4.454	1103991	2.981***	26.724
Income	1.051	2.655	1161398	0.432	0.475	682737	1.928	3.979	461969	1.496***	17.603

Table 1.E3: Descriptive statistics for children by gender

	Full sample			Sample without Electricity			Sample with Electricity			Test of difference	
	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Diff.	T Stud.
Boy											
Round 1											
Labor market time	27.882	20.739	80108	25.535	19.956	59645	34.795	21.504	20328	9.26***	3.003
Home time	8.822	9.56	1823925	10.211	9.921	1284172	5.517	7.695	539619	-4.694***	-17.365
Time for goods	7.387	7.694	1692784	8.398	7.951	1234360	4.667	6.182	458425	-3.731***	-15.954
Time for services	2.31	4.094	1552435	2.471	4.207	1111904	1.903	3.763	440396	-0.568***	-4.368
Leisure time	148.916	20.877	1833929	148.049	20.913	1287055	150.962	20.651	546740	2.913***	4.843
Age	8.231	5.151	2595514	8.281	5.094	1799312	8.118	5.275	796068	-0.163	-1.322
Education	12.096	1.652	516723	11.898	1.621	347374	12.513	1.604	169214	0.615***	7.07
Income	0.355	0.34	46136	0.368	0.235	33424	0.315	0.524	12578	-0.053	-0.804
Round 2											
Labor market time	24.782	19.382	103679	23.595	18.518	74365	27.793	21.122	29314	4.197	1.619
Home time	9.783	10.47	1868650	11.356	10.755	1242029	6.665	9.111	626620	-4.691***	-16.35
Time for goods	8.194	8.677	1759850	9.404	8.934	1209946	5.533	7.417	549904	-3.871***	-15.392
Time for services	2.404	4.346	1605778	2.514	4.427	1084252	2.174	4.165	521526	-0.34**	-2.575
Leisure time	147.766	22.125	1876836	146.674	22.136	1243269	149.909	21.947	633567	3.235***	5.247
Age	8.211	5.154	2667464	8.285	5.09	1741645	8.071	5.27	925819	-0.214*	-1.796
Education	11.981	1.729	531573	11.777	1.753	339803	12.342	1.623	191770	0.566***	6.253
Income	0.356	0.342	54330	0.363	0.327	37683	0.339	0.375	16647	-0.024	-0.376
Girl											
Round 1											
Labor market time	27.302	19.556	78665	22.393	14.031	54161	38.153	24.933	24504	15.761***	6.193
Home time	11.211	11.418	1831205	12.714	11.658	1284883	7.676	9.978	546322	-5.038***	-15.635
Time for goods	6.998	7.273	1692103	7.952	7.43	1234570	4.422	6.132	457533	-3.53***	-15.964
Time for services	5.077	6.51	1710438	5.332	6.514	1222412	4.438	6.456	488026	-0.894***	-4.541
Leisure time	146.006	22.609	1845881	145.257	22.628	1286853	147.728	22.472	559029	2.471***	3.835
Age	8.375	5.189	2607037	8.344	5.106	1807277	8.446	5.371	799760	0.102	0.826
Education	12.237	1.863	560869	12.04	1.937	370737	12.62	1.643	190132	0.58***	6.226
Income	0.328	0.283	49001	0.321	0.125	31590	0.342	0.444	17411	0.021	0.446
Round 2											
Labor market time	25.947	20.72	70663	21.241	16.34	51631	38.781	25.467	18947	17.539***	6.12
Home time	12.157	11.895	1892545	13.478	12.022	1244946	9.618	11.217	647514	-3.86***	-11.841
Time for goods	7.359	7.679	1777675	8.402	7.737	1205454	5.164	7.069	572136	-3.239***	-14.671
Time for services	5.512	7.01	1800621	5.539	6.874	1200728	5.457	7.273	599809	-0.082	-0.406
Leisure time	145.394	23.074	1903489	144.946	22.72	1246482	146.244	23.709	656923	1.298**	2.045
Age	8.334	5.152	2679897	8.279	5.073	1745818	8.438	5.296	933995	0.159	1.339
Education	12.202	1.712	564222	12.049	1.723	347459	12.446	1.666	216678	0.398***	4.705
Income	0.344	0.204	41782	0.373	0.192	29792	0.256	0.105	11905	-0.117***	-3.781

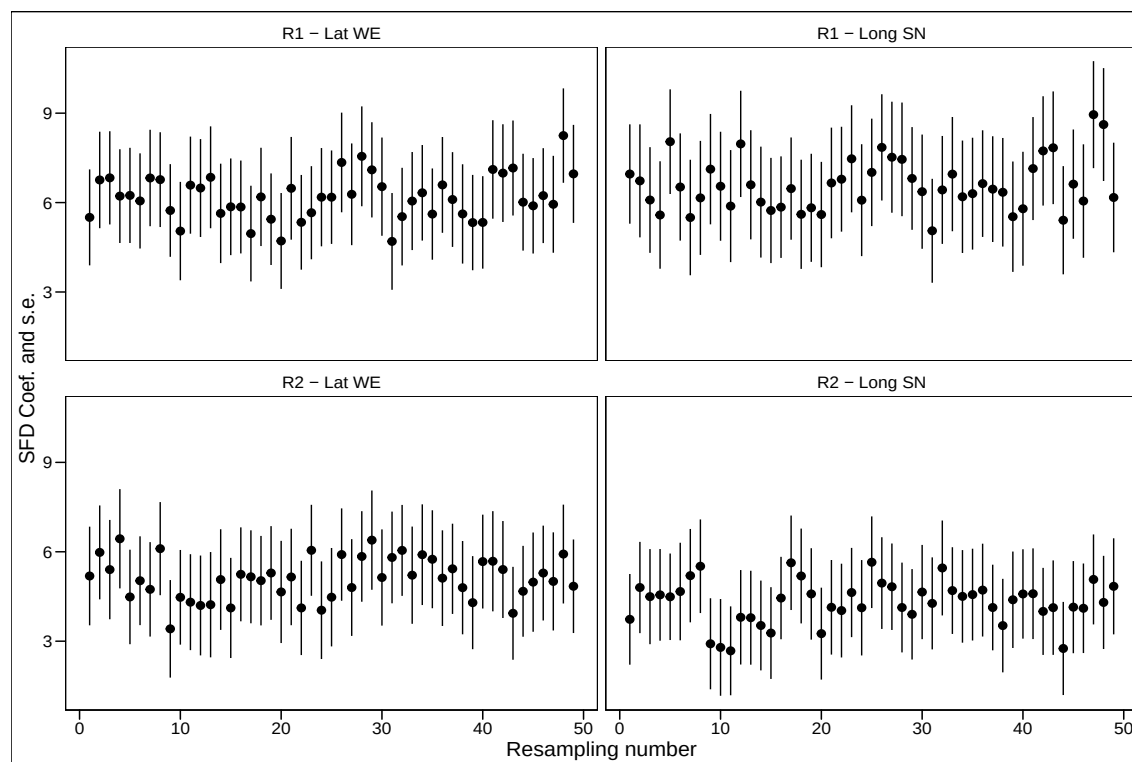
Table 1.E4: Comparison of assumptions and descriptive results

		Time allocation											
		Labor market			Domestic/Home			Leisure			Education		
		Hyp.	Sign obt.	Verified?	Hyp.	Sign obt.	Verified?	Hyp.	Sign obt.	Verified?	Hyp.	Sign obt.	Verified?
Children	Girls	-	+	No	- or Null	-	Yes	+	+	Yes	+	+	Yes
	Boys	-	+	No	- or Null	-	Yes	+	+	Yes	+	+	Yes
Household head	Men	+			- or Null			+/-					
	Women	+			- or Null			+/-					
Adults	Men	+	+	Yes	-	-	Yes	+	?-	No			
	Women	+	+	Yes	-	-	Yes	+	+	Yes			

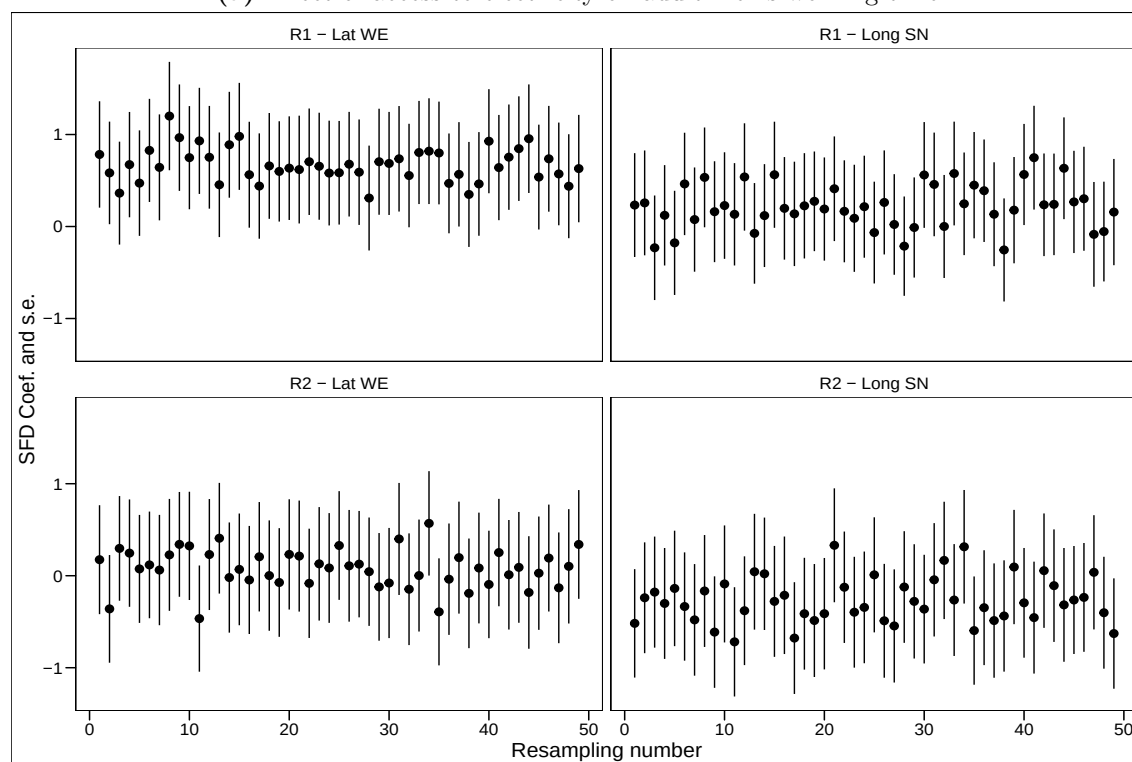
Note: -: statistically negative, +: statistically positive, +/-: statistically positive or negative, - or null:

when the coefficient can be significantly negative or insignificant, No: when the hypothesis is not verified, Yes: if the hypothesis is verified

F Empirical results, discussion and robustness

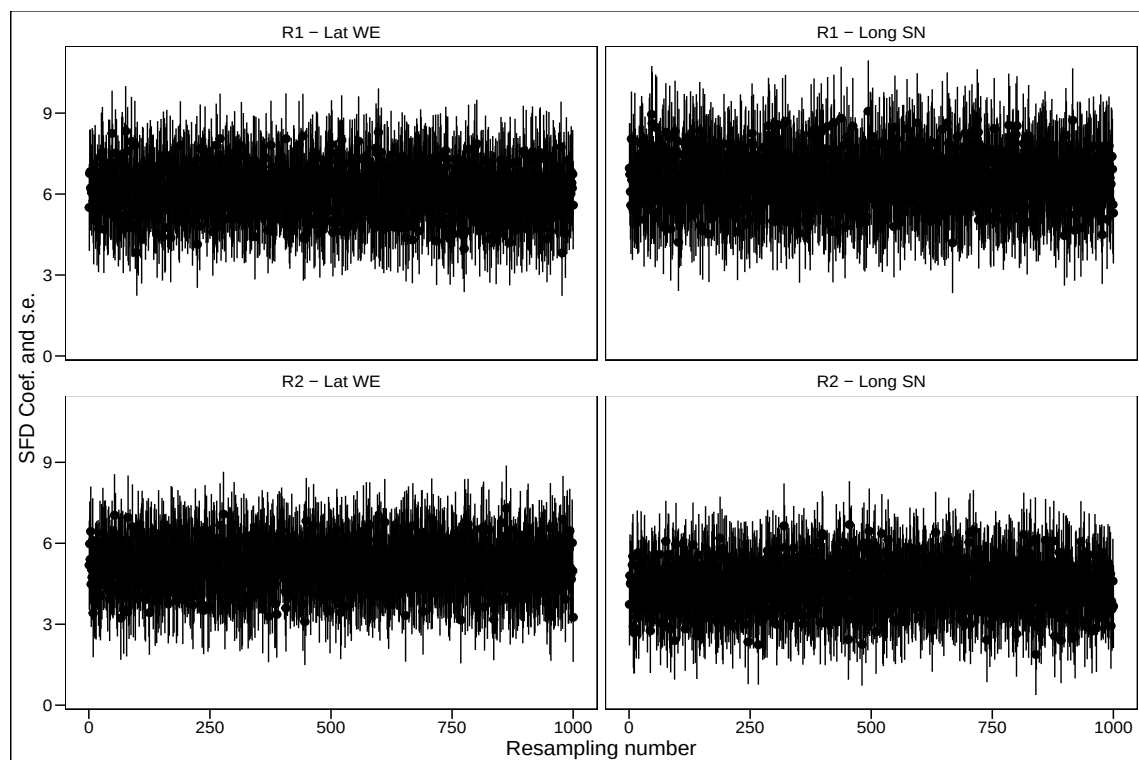


(a) Effect of access to electricity on adult men's working time

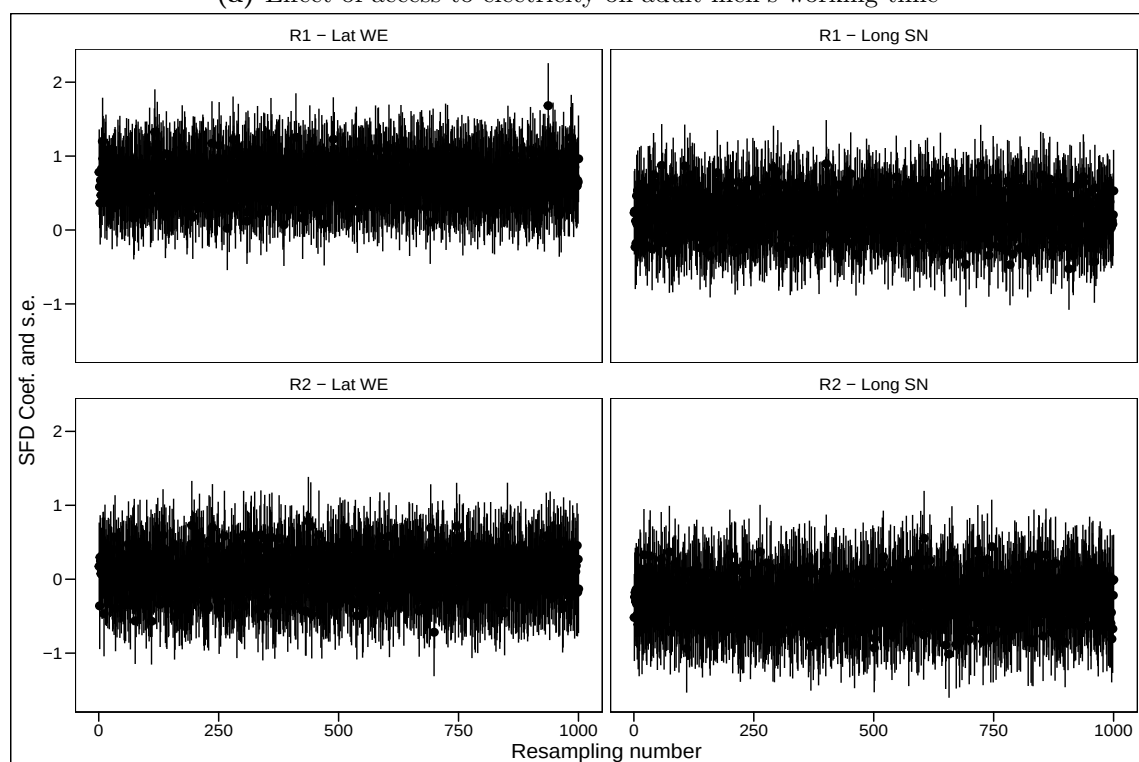


(b) Effect of access to electricity on adult men's domestic work time

Figure 1.F1: Resampling: first 50 iterations

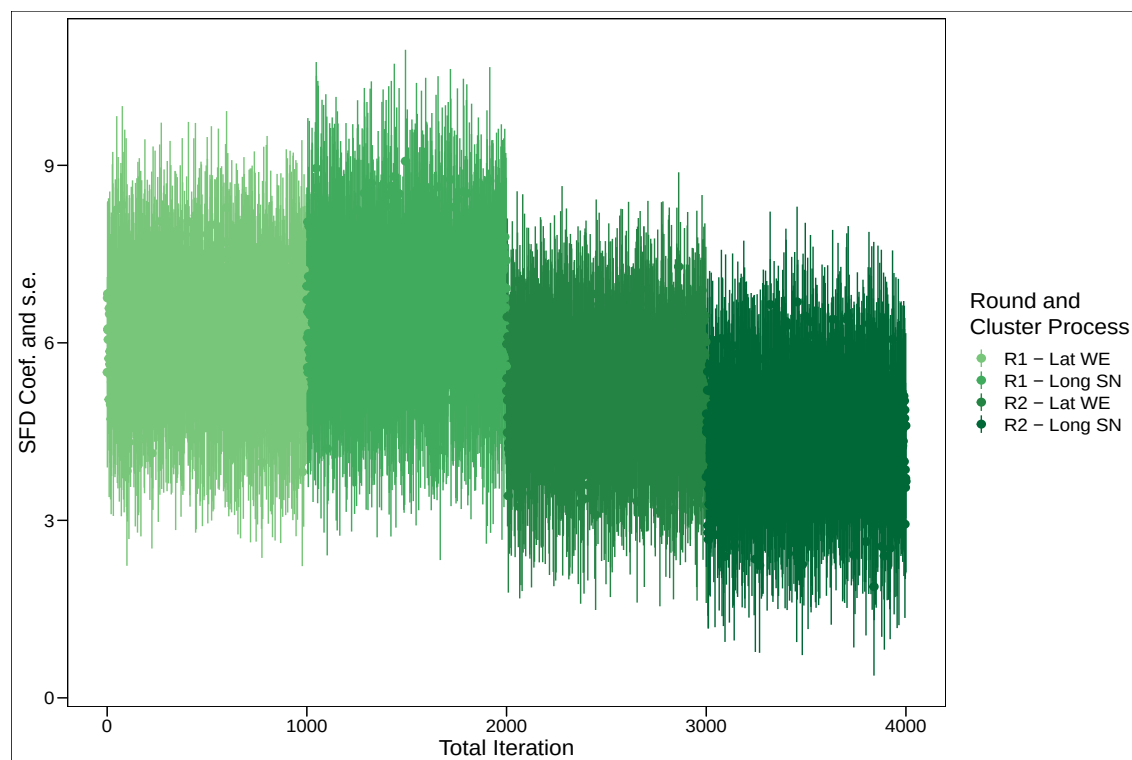


(a) Effect of access to electricity on adult men's working time

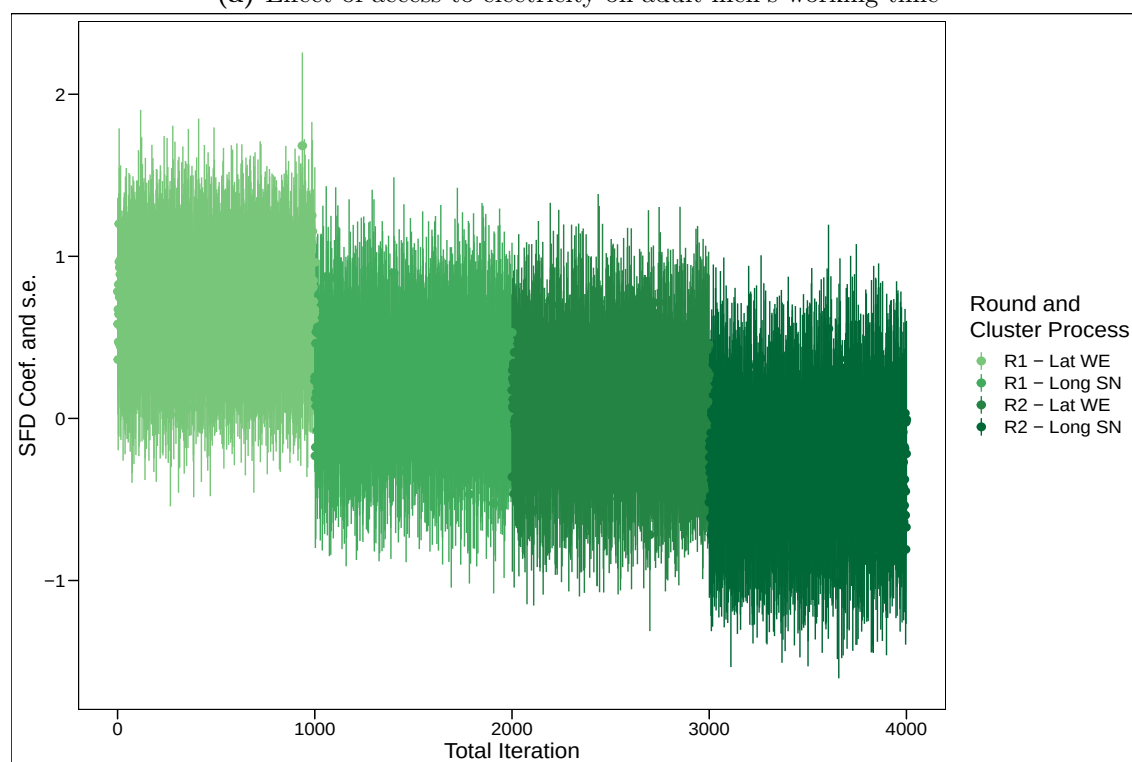


(b) Effect of access to electricity on adult men's domestic work time

Figure 1.F2: Resampling: 1000 iterations

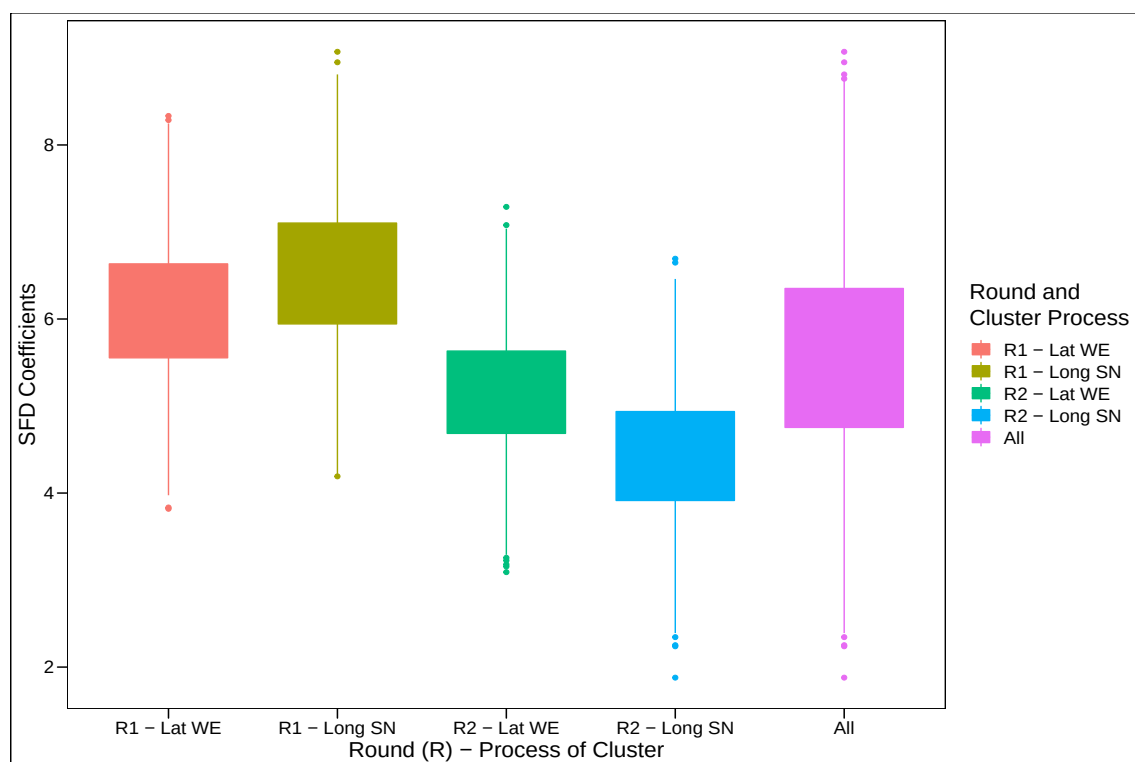


(a) Effect of access to electricity on adult men's working time

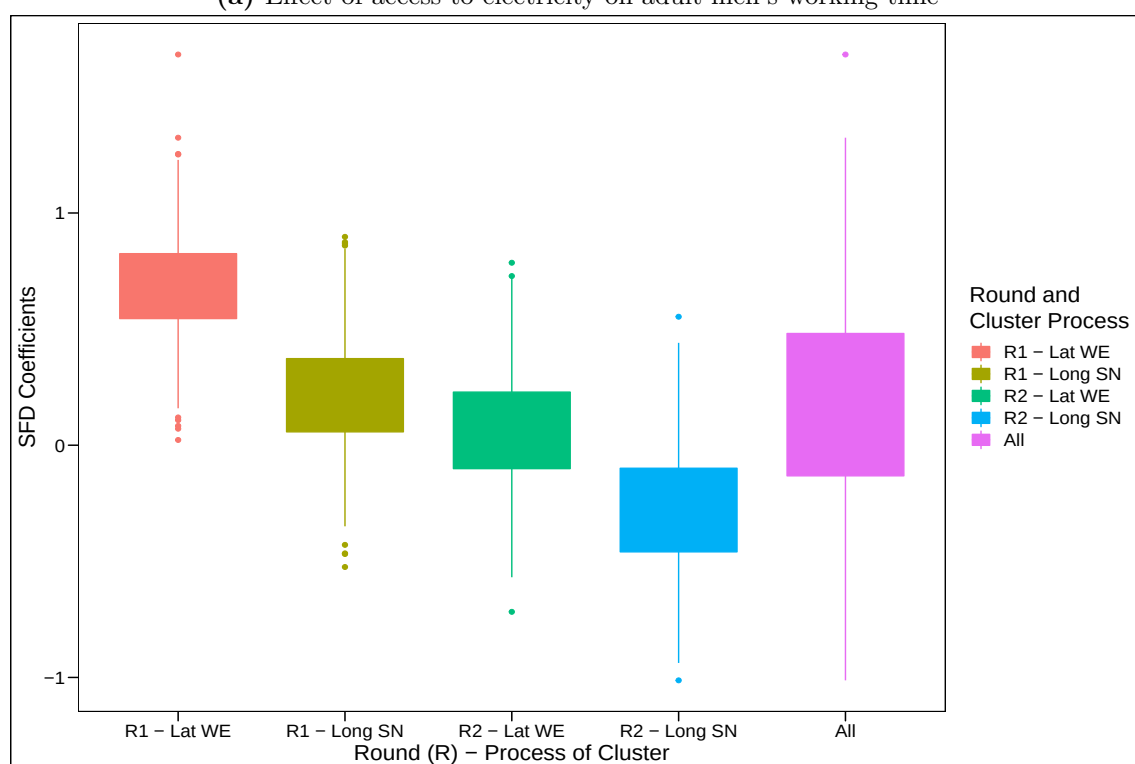


(b) Effect of access to electricity on adult men's domestic work time

Figure 1.F3: Resampling: 4×1000 iterations

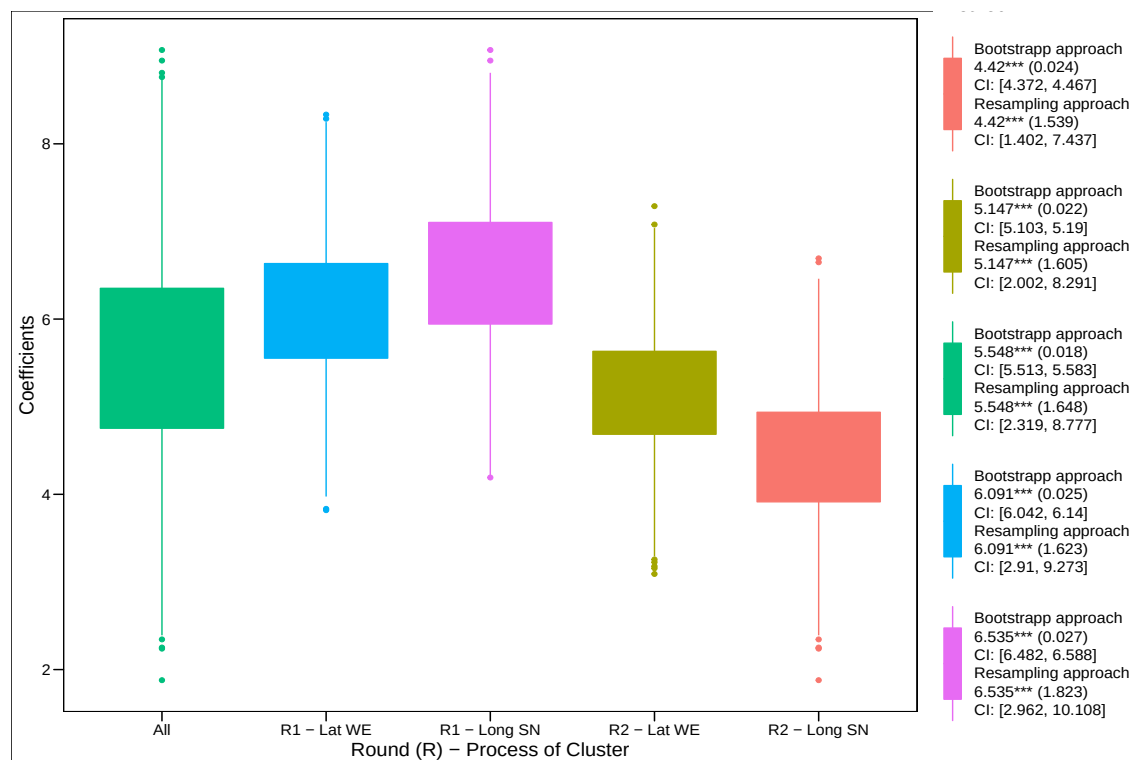


(a) Effect of access to electricity on adult men's working time

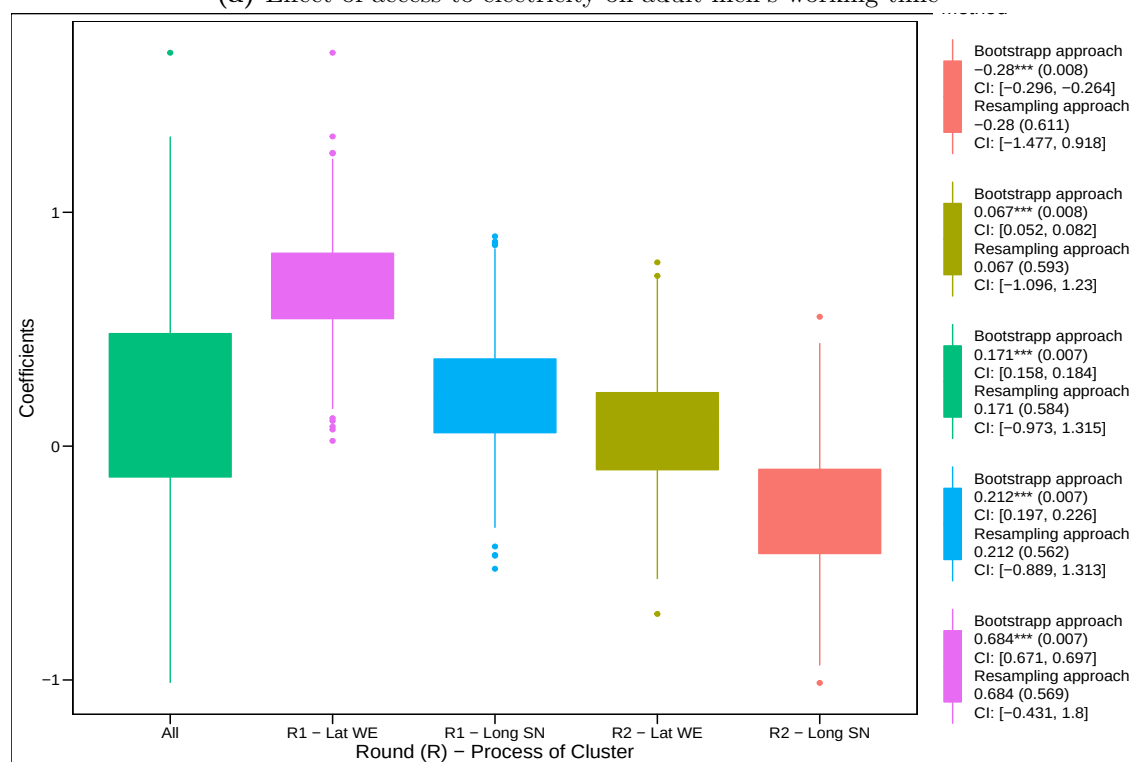


(b) Effect of access to electricity on adult men's domestic work time

Figure 1.F4: Resampling: Distribution of the coefficients



(a) Effect of access to electricity on adult men's working time



(b) Effect of access to electricity on adult men's domestic work time

Figure 1.F5: Resampling: Simple resampling estimation vs Bootstrap estimation

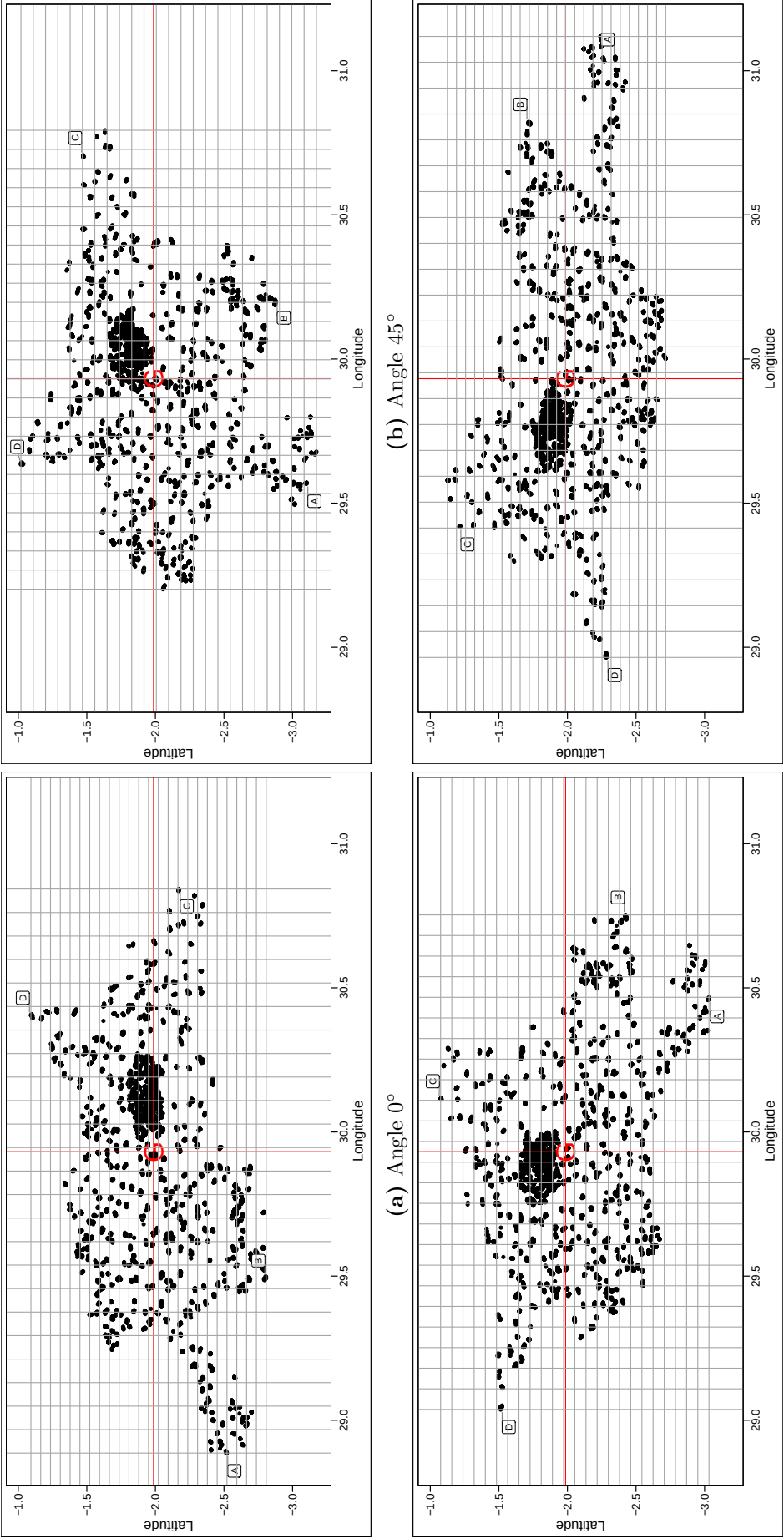


Figure 1.F6: Rotations

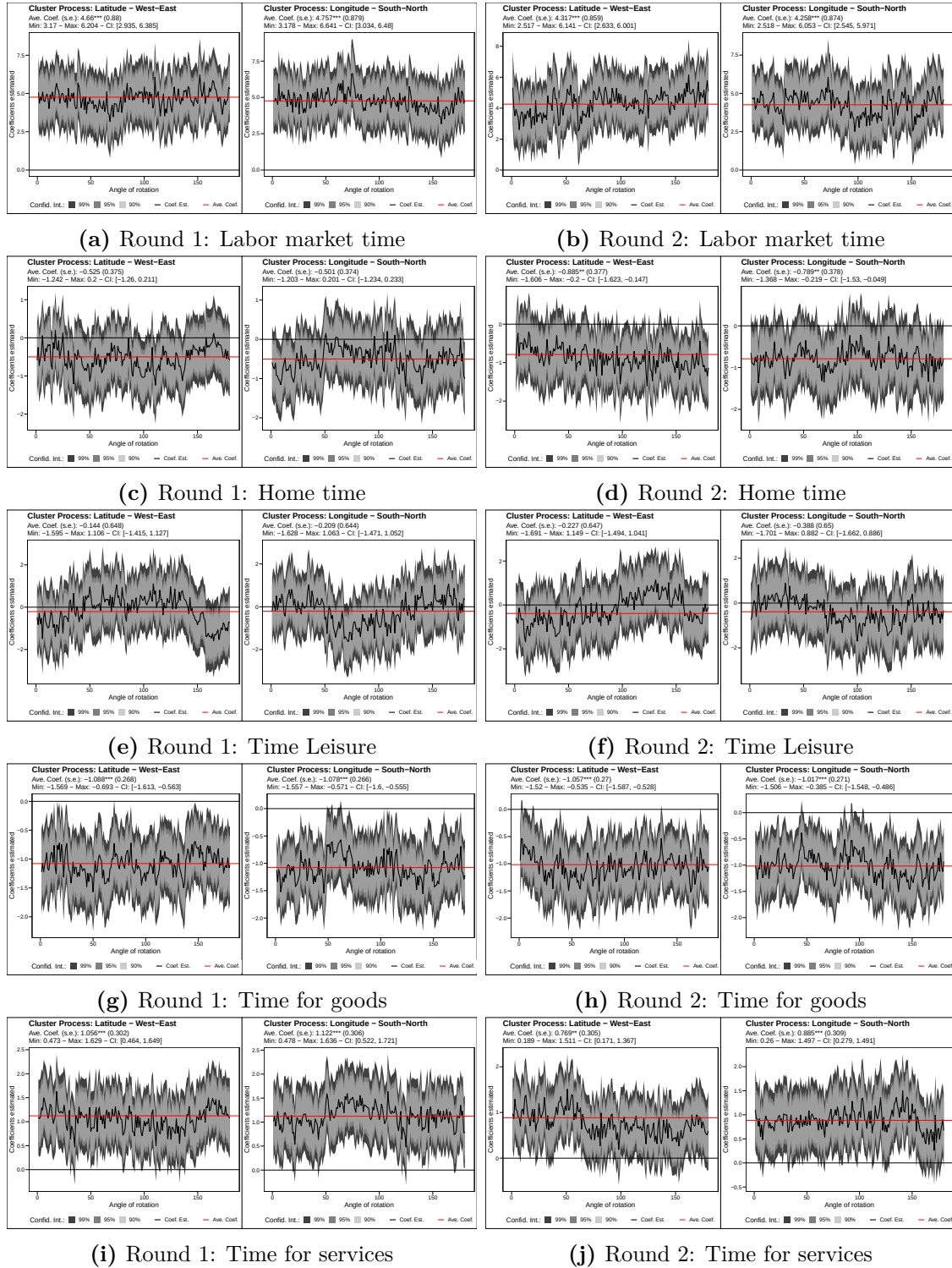
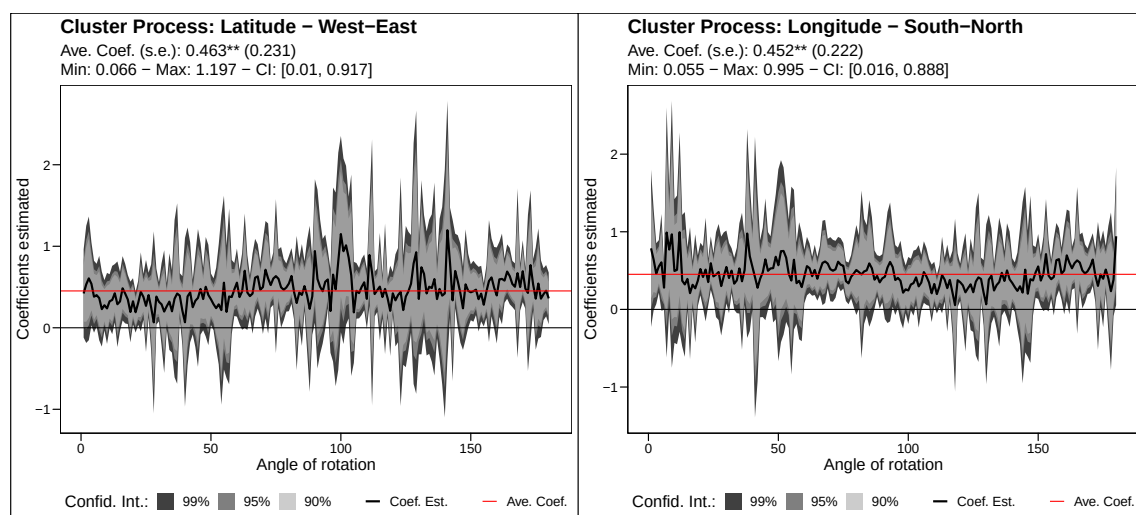
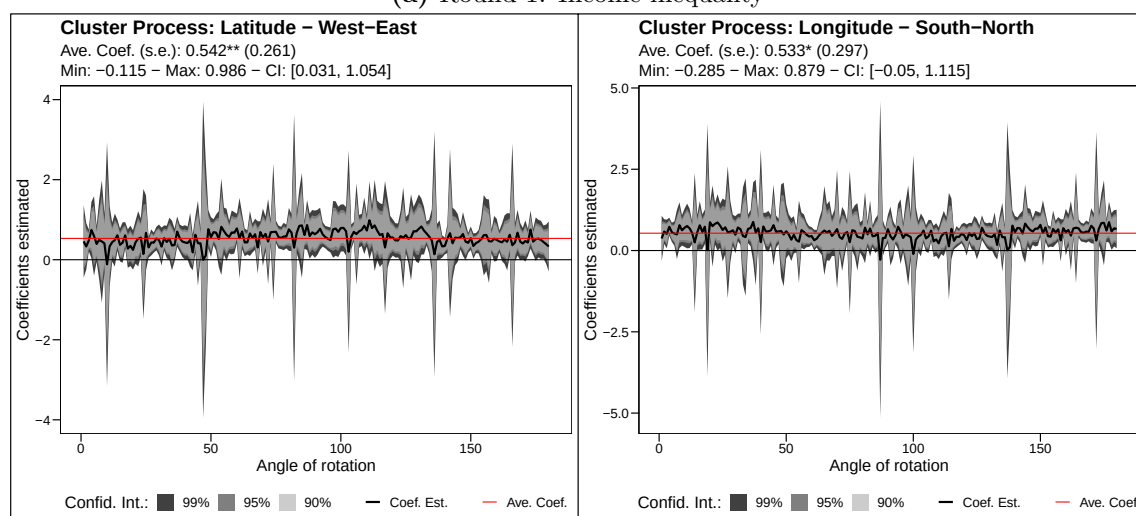


Figure 1.F7: Rotations analysis at household level

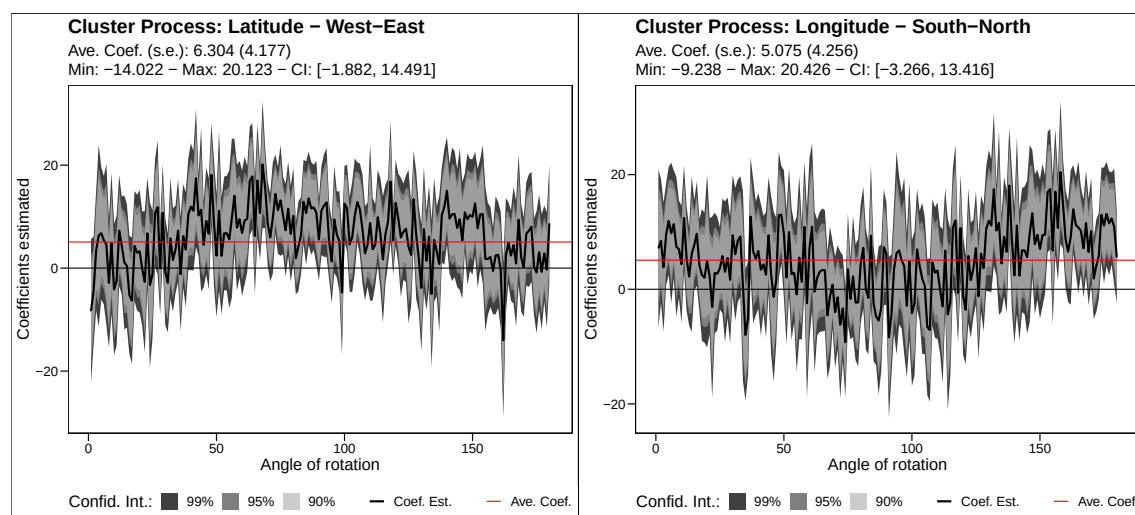


(a) Round 1: Income inequality

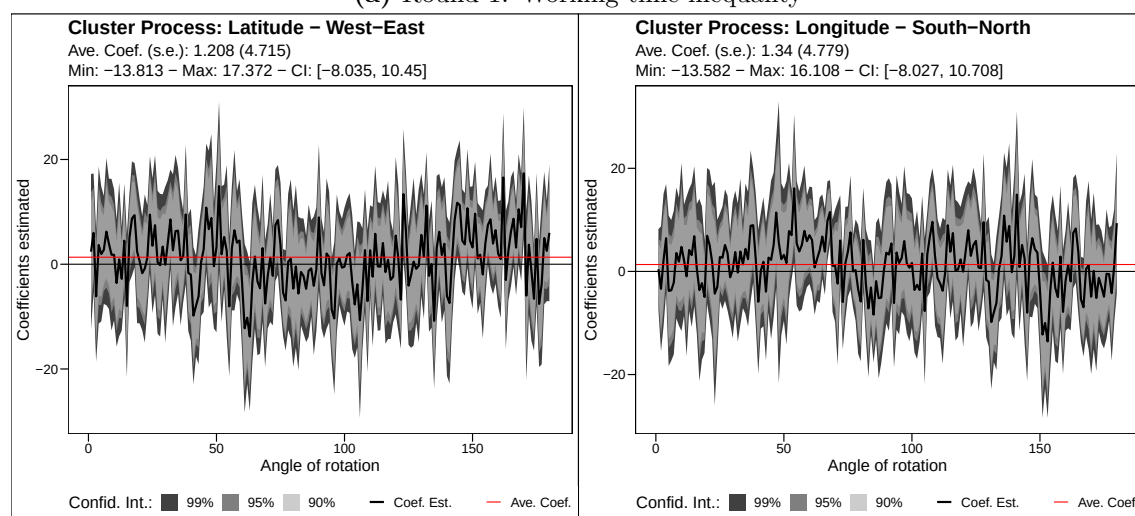


(b) Round 2: Income inequality

Figure 1.F8: Rotation analysis of income inequality



(a) Round 1: Working time inequality



(b) Round 2: Working time inequality

Figure 1.F9: Rotation analysis of working time inequality

Table 1.F1: Analysis at household level

<i>Dependent variable: Average time used in each activity in the household</i>										
	Labor market time				Home time				Leisure time	
Electricity	4.896*** (0.879)	5.260*** (0.881)	4.401*** (0.862)	4.709*** (0.857)	-0.288 (0.385)	-1.034*** (0.343)	-0.628* (0.355)	-1.086*** (0.378)	-1.203* (0.629)	0.237 (0.657)
Age	-0.129*** (0.025)	-0.084*** (0.025)	-0.084*** (0.025)	-0.093*** (0.026)	-0.128*** (0.011)	-0.113*** (0.010)	-0.118*** (0.011)	-0.101*** (0.010)	0.449*** (0.018)	0.420*** (0.018)
HH size	1.180*** (0.260)	0.501* (0.256)	0.541** (0.252)	0.899*** (0.263)	-1.504*** (0.109)	-1.439*** (0.101)	-1.457*** (0.109)	-1.480*** (0.103)	-0.639*** (0.182)	-0.561*** (0.189)
Nb. Children (-13)	-0.982*** (0.315)	-1.295*** (0.316)	-0.240 (0.312)	-1.201*** (0.322)	0.604*** (0.127)	0.580*** (0.124)	0.786*** (0.136)	1.021*** (0.137)	5.079*** (0.226)	4.975*** (0.234)
Education of Head	0.145*** (0.052)	0.167*** (0.056)	0.121** (0.058)	0.197*** (0.056)	-0.004 (0.023)	0.015 (0.023)	-0.008 (0.025)	0.021 (0.027)	-0.113*** (0.042)	-0.114*** (0.043)
Rooms (pc)	3.397*** (1.039)	-0.935 (1.005)	2.484** (1.098)	1.519 (1.038)	-0.574 (0.430)	-0.766* (0.402)	-1.012** (0.487)	-0.851* (0.462)	-0.836 (0.692)	-0.122 (0.788)
Domestic Help	9.960*** (1.706)	8.430*** (1.479)	9.297*** (1.725)	6.878*** (1.697)	-4.703*** (0.713)	-3.277*** (0.652)	-5.027*** (0.940)	-4.216*** (0.637)	0.441 (1.525)	-1.801 (1.203)
Gender	-1.447** (0.705)	-2.414*** (0.727)	-2.934*** (0.690)	-2.043*** (0.709)	-0.076 (0.341)	-0.254 (0.302)	0.415 (0.323)	0.439 (0.293)	2.068*** (0.578)	2.695*** (0.582)
Round	1	1	2	2	1	1	2	2	1	1
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	54	34	61	37	54	34	61	37	54	34
Observations	4,391	4,393	4,453	4,445	6,601	6,625	6,576	6,585	6,601	6,625
R ²	0.318	0.284	0.303	0.299	0.284	0.294	0.263	0.281	0.382	0.381
	Time for goods				Time for services				Leisure time	
Electricity	-1.020*** (0.278)	-1.245*** (0.242)	-0.859*** (0.255)	-1.276*** (0.256)	1.283*** (0.337)	0.850*** (0.306)	0.816*** (0.300)	0.821** (0.321)	-0.583 (0.610)	0.232 (0.672)
Age	-0.0004 (0.008)	0.008 (0.008)	0.003 (0.009)	0.014* (0.008)	-0.077*** (0.008)	-0.079*** (0.008)	-0.076*** (0.008)	-0.065*** (0.008)	0.420*** (0.020)	0.405*** (0.018)
HH size	-0.234*** (0.081)	-0.314*** (0.075)	-0.212*** (0.080)	-0.210** (0.083)	-1.078*** (0.078)	-0.892*** (0.086)	-1.078*** (0.086)	-1.139*** (0.083)	-0.346* (0.200)	-0.456** (0.195)
Nb. Children (-13)	-0.436*** (0.098)	-0.338*** (0.091)	-0.344*** (0.096)	-0.305*** (0.107)	-0.236** (0.098)	-0.362*** (0.099)	-0.049 (0.112)	0.178 (0.109)	4.611*** (0.268)	4.774*** (0.232)
Education of Head	-0.015 (0.017)	0.014 (0.018)	-0.015 (0.019)	0.011 (0.020)	0.025 (0.018)	0.050*** (0.018)	0.035* (0.020)	0.049** (0.020)	-0.129*** (0.046)	-0.176*** (0.045)
Rooms (pc)	-0.183 (0.346)	-0.376 (0.295)	-0.338 (0.365)	-0.373 (0.347)	-1.414*** (0.305)	-1.456*** (0.299)	-1.508*** (0.361)	-1.416*** (0.332)	0.095 (0.748)	-0.157 (0.827)
Domestic Help	-4.441*** (0.524)	-3.257*** (0.481)	-3.803*** (0.644)	-3.942*** (0.535)	0.364 (0.805)	-0.666 (0.673)	-1.075 (0.887)	-0.375 (0.736)	-0.209 (1.629)	-0.148 (1.247)
Gender	-0.267 (0.253)	-0.185 (0.220)	0.054 (0.258)	-0.076 (0.233)	-1.323*** (0.236)	-1.295*** (0.248)	-1.063*** (0.245)	-0.843*** (0.260)	2.356*** (0.603)	1.975*** (0.566)
Round	1	1	2	2	1	1	2	2	1	1
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	54	34	61	37	54	34	61	37	61	37
Observations	6,009	6,032	5,955	5,957	6,518	6,539	6,485	6,490	6,576	6,585
R ²	0.172	0.234	0.153	0.206	0.302	0.303	0.257	0.275	0.367	0.377

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 1.F2: Analysis at household level with male head of household

<i>Dependent variable: Average time used in each activity in the household</i>										
	Labor market time				Home time				Leisure time	
Electricity	4.783*** (1.027)	4.419*** (0.972)	3.713*** (0.954)	4.408*** (0.915)	-0.057 (0.411)	-0.487 (0.435)	-0.996** (0.422)	-0.750* (0.411)	-1.299* (0.715)	-0.673 (0.749)
Age	-0.137*** (0.027)	-0.160*** (0.029)	-0.107*** (0.029)	-0.115*** (0.029)	-0.124*** (0.012)	-0.099*** (0.011)	-0.124*** (0.011)	-0.104*** (0.012)	0.457*** (0.022)	0.433*** (0.022)
HH size	1.102*** (0.269)	0.935*** (0.281)	0.354 (0.344)	0.540* (0.276)	-1.552*** (0.113)	-1.567*** (0.106)	-1.408*** (0.119)	-1.673*** (0.124)	-0.315 (0.230)	-0.422* (0.217)
Nb. Children (-13)	-0.778** (0.328)	-1.118*** (0.351)	-0.043 (0.409)	-0.958*** (0.338)	0.542*** (0.147)	0.708*** (0.138)	0.826*** (0.148)	1.077*** (0.141)	4.650*** (0.272)	4.658*** (0.254)
Education of Head	0.142** (0.066)	0.161** (0.069)	0.131** (0.065)	0.255*** (0.070)	-0.003 (0.027)	0.013 (0.027)	-0.011 (0.028)	-0.004 (0.028)	-0.099* (0.050)	-0.075 (0.051)
Rooms (pc)	3.980*** (1.150)	0.997 (1.122)	2.491 (1.515)	0.585 (1.291)	-2.006*** (0.513)	-1.948*** (0.444)	-1.542*** (0.577)	-2.313*** (0.644)	-0.621 (0.954)	-0.110 (0.982)
Domestic Help	7.128*** (1.683)	7.095*** (1.623)	7.571*** (2.160)	5.729*** (1.811)	-4.000*** (0.786)	-3.911*** (0.771)	-5.402*** (0.960)	-4.469*** (0.677)	-0.510 (1.618)	0.188 (1.435)
Round	1	1	2	2	1	1	2	2	1	1
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	54	34	61	37	54	34	61	37	54	34
Observations	3,493	3,503	3,478	3,510	4,805	4,814	4,736	4,754	4,805	4,814
R ²	0.287	0.238	0.268	0.270	0.293	0.315	0.297	0.314	0.383	0.385
	Time for goods				Time for services				Leisure time	
Electricity	-1.171*** (0.302)	-1.525*** (0.283)	-1.340*** (0.298)	-1.417*** (0.302)	1.697*** (0.350)	1.477*** (0.393)	1.080*** (0.336)	1.079*** (0.353)	-0.228 (0.714)	-0.643 (0.730)
Age	0.012 (0.009)	0.030*** (0.009)	0.008 (0.010)	0.022** (0.010)	-0.090*** (0.010)	-0.086*** (0.009)	-0.088*** (0.010)	-0.086*** (0.010)	0.420*** (0.022)	0.420*** (0.022)
HH size	-0.370*** (0.091)	-0.452*** (0.090)	-0.240*** (0.087)	-0.338*** (0.103)	-1.108*** (0.099)	-1.090*** (0.094)	-1.147*** (0.104)	-1.282*** (0.102)	-0.094 (0.219)	-0.121 (0.218)
Nb. Children (-13)	-0.272** (0.112)	-0.088 (0.107)	-0.115 (0.112)	-0.083 (0.111)	-0.227* (0.118)	-0.186 (0.119)	-0.012 (0.126)	0.167 (0.128)	4.240*** (0.274)	4.426*** (0.257)
Education of Head	-0.007 (0.021)	-0.003 (0.021)	-0.014 (0.020)	0.001 (0.020)	0.028 (0.024)	0.059** (0.023)	0.021 (0.024)	0.046** (0.022)	-0.166*** (0.051)	-0.163*** (0.054)
Rooms (pc)	-0.471 (0.453)	-0.400 (0.369)	-0.118 (0.451)	-0.441 (0.516)	-2.225*** (0.410)	-2.123*** (0.371)	-2.097*** (0.405)	-2.669*** (0.460)	0.036 (1.135)	0.644 (1.103)
Domestic Help	-4.092*** (0.623)	-3.488*** (0.599)	-3.818*** (0.677)	-3.393*** (0.564)	1.345 (0.871)	-0.397 (0.850)	-1.989** (1.011)	-1.775** (0.837)	-0.217 (1.995)	0.594 (1.506)
Round	1	1	2	2	1	1	2	2	2	2
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	54	34	61	37	54	34	61	37	61	37
Observations	4,415	4,413	4,328	4,311	4,746	4,754	4,678	4,691	4,736	4,754
R ²	0.179	0.254	0.156	0.208	0.317	0.338	0.292	0.305	0.389	0.388

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 1.F3: Analysis at household level with female head of household

<i>Dependent variable: Average time used in each activity in the household</i>										
	Labor market time				Home time				Leisure time	
Electricity	3.588*	5.515***	2.728	4.099**	-0.980	-1.269	-1.683**	-1.340*	1.211	0.103
	(2.167)	(1.988)	(2.016)	(1.864)	(0.917)	(0.812)	(0.820)	(0.774)	(1.458)	(1.433)
Age	-0.033	0.010	0.004	-0.054	-0.128***	-0.101***	-0.123***	-0.073***	0.410***	0.364***
	(0.047)	(0.051)	(0.050)	(0.055)	(0.020)	(0.017)	(0.019)	(0.020)	(0.032)	(0.033)
HH size	1.524***	1.667***	1.440**	1.903***	-1.498***	-1.523***	-1.557***	-1.399***	-1.694***	-1.402***
	(0.456)	(0.591)	(0.620)	(0.616)	(0.214)	(0.202)	(0.218)	(0.217)	(0.361)	(0.408)
Nb. Children (-13)	-2.394***	-2.905***	-1.582**	-2.721***	0.415	0.270	0.670***	0.899***	7.013***	6.878***
	(0.684)	(0.751)	(0.621)	(0.745)	(0.281)	(0.275)	(0.256)	(0.295)	(0.519)	(0.599)
Education of Head	0.323***	0.246**	0.308***	0.161	0.058	-0.0001	0.063	0.060	-0.238***	-0.072
	(0.097)	(0.107)	(0.116)	(0.104)	(0.050)	(0.038)	(0.049)	(0.046)	(0.079)	(0.074)
Rooms (pc)	-0.610	-2.647	2.618	0.025	0.292	0.423	0.809	0.456	0.307	-0.785
	(1.815)	(2.009)	(2.169)	(2.236)	(0.678)	(0.597)	(0.617)	(0.738)	(1.201)	(1.343)
Domestic Help	18.909***	17.507***	16.446***	6.905*	-5.149***	-4.461***	-6.293***	-4.841***	-1.392	-1.602
	(3.337)	(2.682)	(4.301)	(3.614)	(1.711)	(1.231)	(1.917)	(1.153)	(3.153)	(2.463)
Round	1	1	2	2	1	1	2	2	1	1
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	48	33	56	36	53	34	59	37	53	34
Observations	907	903	971	968	1,805	1,798	1,833	1,846	1,805	1,798
R ²	0.405	0.418	0.375	0.348	0.236	0.264	0.256	0.243	0.344	0.335
	Time for goods				Time for services				Leisure time	
Electricity	-0.548	-0.428	-1.445***	-0.545	-0.017	-0.508	-0.146	-0.200	1.304	-0.161
	(0.607)	(0.522)	(0.490)	(0.457)	(0.616)	(0.657)	(0.656)	(0.694)	(1.344)	(1.143)
Age	-0.019	0.014	-0.019	0.014	-0.041***	-0.045***	-0.035***	-0.029**	0.382***	0.324***
	(0.015)	(0.014)	(0.016)	(0.014)	(0.014)	(0.013)	(0.012)	(0.014)	(0.036)	(0.037)
HH size	-0.130	-0.243	-0.058	-0.081	-0.667***	-0.580***	-0.939***	-0.930***	-1.468***	-1.359***
	(0.175)	(0.159)	(0.160)	(0.180)	(0.143)	(0.142)	(0.169)	(0.149)	(0.431)	(0.402)
Nb. Children (-13)	-0.925***	-0.765***	-0.982***	-0.542**	-0.535***	-0.652***	0.218	0.168	6.354***	6.158***
	(0.206)	(0.205)	(0.204)	(0.217)	(0.181)	(0.206)	(0.222)	(0.201)	(0.479)	(0.578)
Education of Head	-0.001	-0.002	0.023	0.024	0.086***	0.061**	0.038	0.045	-0.204**	-0.142*
	(0.035)	(0.030)	(0.041)	(0.035)	(0.032)	(0.026)	(0.031)	(0.031)	(0.089)	(0.074)
Rooms (pc)	-0.161	0.159	-0.059	0.104	-0.803*	-0.696*	-0.154	-0.502	-0.817	1.273
	(0.478)	(0.499)	(0.466)	(0.577)	(0.460)	(0.370)	(0.396)	(0.453)	(1.154)	(1.240)
Domestic Help	-3.868***	-3.017***	-2.402	-2.494**	-1.376	-1.961*	-2.593	-0.596	2.359	-0.748
	(1.417)	(0.906)	(1.530)	(1.131)	(1.111)	(1.136)	(1.629)	(1.075)	(2.810)	(2.865)
Round	1	1	2	2	1	1	2	2	2	2
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	53	34	59	37	53	34	59	37	59	37
Observations	1,598	1,590	1,620	1,624	1,780	1,774	1,800	1,808	1,833	1,846
R ²	0.158	0.205	0.161	0.184	0.210	0.215	0.217	0.244	0.353	0.323

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 1.F4: Analysis at the level of the head of household

<i>Dependent variable: Time used in each activity of the head of household</i>										
	Labor market time				Home time				Leisure time	
Electricity	7.576*** (1.514)	7.090*** (1.536)	6.764*** (1.679)	3.410** (1.397)	0.873 (0.614)	-0.943 (0.591)	0.319 (0.564)	-0.674 (0.560)	-5.635*** (1.134)	-1.793 (1.152)
Age	-0.269*** (0.046)	-0.144*** (0.049)	-0.133** (0.056)	-0.205*** (0.052)	-0.176*** (0.015)	-0.166*** (0.015)	-0.177*** (0.016)	-0.146*** (0.016)	0.694*** (0.029)	0.668*** (0.029)
HH size	0.790* (0.445)	0.014 (0.495)	-0.060 (0.490)	1.039** (0.512)	-0.700*** (0.162)	-0.682*** (0.157)	-0.914*** (0.180)	-0.731*** (0.171)	-0.466 (0.324)	-0.531 (0.345)
Nb. Children (-13)	-0.215 (0.542)	-0.333 (0.594)	1.156* (0.625)	-0.562 (0.626)	0.629*** (0.214)	0.397* (0.206)	0.930*** (0.246)	0.875*** (0.228)	-0.436 (0.438)	-0.071 (0.432)
Education of Head	0.124 (0.090)	0.239** (0.105)	0.203** (0.094)	0.193* (0.103)	-0.021 (0.037)	0.027 (0.038)	-0.030 (0.040)	0.015 (0.042)	-0.186*** (0.072)	-0.220*** (0.076)
Rooms (pc)	3.849** (1.687)	-3.102* (1.761)	0.662 (1.860)	0.333 (1.752)	1.649*** (0.566)	1.130** (0.542)	1.161* (0.627)	1.132* (0.635)	-2.150* (1.124)	-1.253 (1.183)
Domestic Help	12.744*** (3.004)	5.750* (3.098)	3.065 (4.345)	8.945*** (3.295)	-7.338*** (1.217)	-4.516*** (1.038)	-2.678*** (1.026)	-3.183*** (0.887)	5.112* (2.864)	-0.281 (2.323)
Gender	-4.493*** (1.222)	-9.900*** (1.394)	-7.927*** (1.308)	-5.006*** (1.359)	9.320*** (0.531)	9.702*** (0.555)	11.042*** (0.537)	11.227*** (0.519)	-6.006*** (0.937)	-5.172*** (1.013)
Round	1	1	2	2	1	1	2	2	1	1
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	54	34	60	36	54	34	61	37	54	34
Observations	2,208	2,172	2,344	2,327	6,601	6,625	6,574	6,583	6,601	6,625
R ²	0.442	0.487	0.388	0.428	0.259	0.300	0.274	0.292	0.310	0.320
	Time for goods				Time for services				Leisure time	
Electricity	2.254*** (0.756)	0.804 (0.720)	2.254*** (0.721)	1.001 (0.843)	0.949 (0.742)	-0.944 (0.718)	-1.862*** (0.674)	-0.581 (0.613)	-3.648*** (1.147)	-1.996* (1.202)
Age	-0.020 (0.018)	-0.004 (0.018)	-0.035** (0.018)	-0.016 (0.021)	-0.068*** (0.017)	-0.065*** (0.016)	-0.074*** (0.016)	-0.044** (0.019)	0.690*** (0.032)	0.666*** (0.032)
HH size	-0.173 (0.201)	-0.294 (0.228)	-0.156 (0.231)	0.003 (0.249)	-0.731*** (0.181)	-0.374* (0.200)	-0.491** (0.236)	-0.450** (0.227)	-0.243 (0.343)	-0.444 (0.360)
Nb. Children (-13)	0.014 (0.254)	0.301 (0.269)	0.017 (0.296)	0.156 (0.313)	0.958*** (0.234)	0.488* (0.250)	0.873*** (0.309)	0.824*** (0.305)	-0.838* (0.454)	-0.570 (0.457)
Education of Head	-0.014 (0.040)	-0.029 (0.048)	0.002 (0.044)	0.129** (0.052)	-0.031 (0.038)	0.108*** (0.038)	-0.005 (0.040)	0.066 (0.042)	-0.154* (0.080)	-0.260*** (0.079)
Rooms (pc)	0.751 (0.591)	-0.131 (0.632)	-0.599 (0.638)	0.421 (0.792)	0.119 (0.520)	-0.117 (0.514)	-0.120 (0.562)	-0.188 (0.619)	-1.704 (1.141)	-1.818 (1.191)
Domestic Help	-6.781*** (1.725)	-0.447 (1.490)	-6.522* (3.356)	-8.003*** (2.648)	-6.375*** (2.227)	-4.966** (2.160)	-0.350 (1.646)	-3.824* (1.969)	1.578 (2.716)	3.664 (2.396)
Gender	-0.702 (0.509)	-1.177** (0.549)	-0.415 (0.560)	0.970 (0.681)	7.141*** (0.516)	8.204*** (0.527)	8.086*** (0.513)	7.320*** (0.571)	-4.950*** (1.015)	-4.981*** (0.997)
Round	1	1	2	2	1	1	2	2	2	2
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	54	34	59	37	54	34	60	37	61	37
Observations	2,647	2,653	2,549	2,532	2,446	2,474	2,474	2,479	6,576	6,585
R ²	0.217	0.304	0.201	0.289	0.445	0.457	0.412	0.396	0.297	0.300

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 1.F5: Analysis at male heads of household

<i>Dependent variable: Time used in each activity of the male head of household</i>										
	Labor market time				Home time				Leisure time	
Electricity	8.913*** (1.766)	7.854*** (1.945)	6.747*** (1.541)	4.699*** (1.606)	0.463 (0.673)	-0.155 (0.605)	0.274 (0.683)	-0.048 (0.597)	-7.103*** (1.268)	-4.649*** (1.319)
Age	-0.290*** (0.053)	-0.193*** (0.056)	-0.128** (0.052)	-0.163*** (0.054)	-0.118*** (0.016)	-0.087*** (0.015)	-0.116*** (0.018)	-0.088*** (0.019)	0.649*** (0.034)	0.621*** (0.036)
HH size	0.951* (0.516)	-0.051 (0.601)	-0.347 (0.585)	0.636 (0.517)	-0.773*** (0.182)	-0.793*** (0.163)	-0.738*** (0.191)	-0.976*** (0.185)	-0.238 (0.435)	-0.417 (0.406)
Nb. Children (-13)	-0.361 (0.678)	0.576 (0.801)	1.479** (0.671)	-0.531 (0.584)	0.408* (0.240)	0.430** (0.204)	0.801*** (0.233)	1.045*** (0.235)	-0.733 (0.548)	-0.100 (0.501)
Education of Head	0.101 (0.115)	0.243* (0.139)	0.121 (0.121)	0.403*** (0.115)	-0.037 (0.041)	-0.001 (0.040)	-0.069 (0.046)	-0.034 (0.049)	-0.095 (0.096)	-0.073 (0.104)
Rooms (pc)	3.528* (2.117)	0.012 (1.747)	0.695 (2.241)	-0.098 (1.740)	1.661** (0.655)	1.422** (0.650)	2.499*** (0.870)	2.310*** (0.833)	-3.899** (1.642)	-2.120 (1.522)
Domestic Help	8.100** (3.173)	0.326 (3.468)	3.377 (4.354)	5.377* (3.108)	-5.987*** (1.084)	-4.396*** (0.978)	-2.322** (0.968)	-2.898*** (0.911)	4.850 (3.045)	-0.519 (2.772)
Round	1	1	2	2	1	1	2	2	1	1
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	54	34	59	37	54	34	61	37	54	34
Observations	1,915	1,896	2,089	2,098	4,805	4,814	4,735	4,752	4,805	4,814
R ²	0.387	0.394	0.342	0.362	0.175	0.236	0.182	0.222	0.291	0.286
	Time for goods				Time for services				Leisure time	
Electricity	1.291 (1.099)	0.551 (0.841)	2.202** (0.948)	0.315 (0.945)	-0.885 (0.716)	0.705 (0.883)	-1.413 (0.900)	-0.664 (0.921)	-3.323** (1.418)	-3.392*** (1.314)
Age	-0.043* (0.023)	0.028 (0.023)	-0.039 (0.025)	-0.027 (0.026)	-0.029 (0.019)	-0.009 (0.021)	-0.041* (0.025)	-0.026 (0.028)	0.638*** (0.038)	0.648*** (0.039)
HH size	-0.176 (0.237)	-0.623*** (0.240)	-0.301 (0.251)	-0.082 (0.273)	-0.873*** (0.249)	-0.014 (0.257)	0.547* (0.320)	-0.090 (0.347)	-0.748* (0.422)	-0.347 (0.421)
Nb. Children (-13)	-0.246 (0.301)	0.661** (0.259)	0.242 (0.328)	0.763** (0.349)	0.919*** (0.293)	0.099 (0.335)	-0.553 (0.406)	-0.223 (0.451)	-0.179 (0.518)	-0.365 (0.505)
Education of Head	-0.010 (0.048)	0.007 (0.058)	-0.014 (0.056)	0.065 (0.065)	-0.037 (0.050)	0.045 (0.052)	-0.006 (0.065)	0.021 (0.064)	-0.084 (0.094)	-0.246** (0.102)
Rooms (pc)	-0.478 (0.812)	-1.176 (0.823)	-0.856 (1.039)	0.564 (1.238)	0.951* (0.553)	1.042 (0.686)	1.956** (0.796)	0.381 (0.956)	-4.086** (1.664)	-1.347 (1.672)
Domestic Help	-5.353** (2.308)	-1.102 (1.854)	-7.484* (4.005)	-9.900*** (3.161)	-2.324 (2.018)	-3.011* (1.715)	-3.707 (2.996)	-2.838 (3.550)	3.505 (3.488)	2.906 (3.036)
Round	1	1	2	2	1	1	2	2	2	2
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	54	34	60	34	53	34	59	35	61	37
Observations	1,825	1,834	1,7	1,68	1,277	1,284	1,242	1,226	4,736	4,754
R ²	0.213	0.357	0.190	0.335	0.404	0.355	0.363	0.403	0.258	0.286

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 1.F6: Analysis at female heads of household

<i>Dependent variable: Time used in each activity of the female head of household</i>										
	Labor market time				Home time				Leisure time	
Electricity	-0.850 (3.200)	5.202 (4.233)	11.327** (5.108)	5.952 (4.800)	-0.491 (1.661)	-0.796 (1.472)	-0.592 (1.352)	-0.820 (1.342)	0.913 (2.492)	1.926 (2.272)
Age	-0.476*** (0.105)	-0.295** (0.121)	-0.245** (0.116)	-0.406** (0.155)	-0.272*** (0.031)	-0.252*** (0.027)	-0.328*** (0.030)	-0.301*** (0.031)	0.805*** (0.048)	0.777*** (0.047)
HH size	3.197*** (1.129)	1.674 (1.066)	0.822 (1.392)	0.728 (1.722)	-1.403*** (0.376)	-1.534*** (0.332)	-1.842*** (0.391)	-1.815*** (0.383)	0.213 (0.557)	-0.055 (0.591)
Nb. Children (-13)	-6.798*** (1.198)	-3.382** (1.609)	-1.017 (1.649)	-3.849 (2.453)	1.766*** (0.520)	1.209** (0.554)	1.780*** (0.503)	1.992*** (0.515)	-0.233 (0.886)	-0.200 (0.915)
Education of Head	0.199 (0.161)	0.502** (0.240)	0.333 (0.210)	0.275 (0.247)	0.022 (0.079)	0.037 (0.072)	0.089 (0.079)	0.093 (0.073)	-0.343** (0.134)	-0.243** (0.118)
Rooms (pc)	-3.791 (2.822)	-2.928 (4.658)	-0.767 (3.789)	-2.643 (7.102)	1.170 (0.944)	-0.005 (0.849)	1.885** (0.917)	1.780* (1.000)	0.511 (1.735)	-1.768 (1.911)
Domestic Help	6.499 (9.114)	13.548 (8.745)	11.940 (10.956)	30.755** (12.018)	-6.263* (3.310)	-6.634*** (2.013)	-6.278** (3.120)	-1.544 (2.213)	10.286*** (3.914)	13.863*** (3.674)
Round	1	1	2	2	1	1	2	2	1	1
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	41	33	46	33	53	34	59	37	53	34
Observations	331	326	312	309	1,805	1,798	1,833	1,846	1,805	1,798
R ²	0.665	0.628	0.713	0.708	0.229	0.245	0.286	0.302	0.408	0.387
	Time for goods				Time for services				Leisure time	
Electricity	-0.260 (1.064)	-0.022 (1.211)	0.437 (1.257)	1.538 (1.384)	1.601 (1.137)	0.673 (1.106)	0.460 (1.010)	0.301 (0.992)	-0.607 (2.314)	-2.492 (2.121)
Age	-0.010 (0.030)	-0.001 (0.028)	-0.136*** (0.033)	-0.078** (0.035)	-0.102*** (0.023)	-0.105*** (0.022)	-0.090*** (0.024)	-0.119*** (0.024)	0.850*** (0.053)	0.808*** (0.059)
HH size	-0.086 (0.370)	0.053 (0.352)	0.748* (0.392)	-0.372 (0.412)	-0.919*** (0.306)	-1.088*** (0.308)	-1.595*** (0.309)	-1.645*** (0.314)	0.559 (0.654)	0.871 (0.668)
Nb. Children (-13)	-0.747 (0.578)	-1.158** (0.474)	-1.445*** (0.472)	-0.388 (0.525)	1.853*** (0.390)	1.642*** (0.429)	2.413*** (0.414)	2.331*** (0.388)	-1.169 (0.867)	-1.351 (0.939)
Education of Head	0.152*** (0.053)	0.054 (0.077)	0.011 (0.074)	0.089 (0.073)	0.004 (0.052)	0.072 (0.053)	0.067 (0.059)	0.031 (0.048)	-0.318*** (0.122)	-0.323** (0.128)
Rooms (pc)	-0.263 (0.980)	-0.691 (0.995)	1.369 (0.880)	2.058** (0.856)	-0.534 (0.641)	-0.880 (0.608)	-0.654 (0.648)	-1.095 (0.687)	-3.244** (1.489)	-1.244 (1.783)
Domestic Help	-7.399*** (2.030)	-5.092** (2.072)	-3.469 (2.737)	-1.131 (2.942)	-2.317 (2.275)	-3.056 (2.158)	-4.576* (2.678)	-0.348 (1.964)	6.024 (5.309)	1.828 (4.604)
Round	1	1	2	2	1	1	2	2	2	2
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	51	33	56	36	53	34	59	37	59	37
Observations	821	808	839	828	1,398	1,389	1,487	1,490	1,833	1,846
R ²	0.205	0.216	0.232	0.298	0.287	0.297	0.319	0.345	0.433	0.405

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 1.F7: Classique panel regressions for male heads of household sample

<i>Dependent variable: Labor market time</i>								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Electricity	10.009*** (0.044)	9.836*** (1.026)	10.324*** (0.043)	11.125*** (1.010)	9.764*** (0.041)	7.529*** (0.963)	10.656*** (0.040)	7.963*** (0.912)
Age	-0.189*** (0.002)	-0.202*** (0.042)	-0.198*** (0.002)	-0.216*** (0.042)	-0.131*** (0.002)	-0.133*** (0.041)	-0.128*** (0.002)	-0.135*** (0.040)
HH size	0.729*** (0.018)	0.766* (0.399)	0.754*** (0.017)	0.500 (0.401)	0.308*** (0.016)	0.533 (0.375)	0.195*** (0.016)	0.399 (0.372)
Nb. Children (-13)	-0.561*** (0.022)	-0.035 (0.488)	-0.664*** (0.021)	-0.481 (0.498)	-0.376*** (0.020)	-0.052 (0.473)	-0.430*** (0.020)	-0.126 (0.460)
Education of Head	0.262*** (0.004)	0.293*** (0.087)	0.274*** (0.004)	0.266*** (0.090)	0.261*** (0.004)	0.260*** (0.086)	0.295*** (0.004)	0.300*** (0.086)
Rooms (pc)	2.638*** (0.058)	2.484** (1.248)	2.376*** (0.057)	-0.060 (1.244)	0.622*** (0.060)	2.672** (1.307)	-0.062 (0.059)	2.020 (1.305)
Domestic Help	6.598*** (0.079)	7.781*** (2.384)	6.447*** (0.077)	6.934*** (2.139)	3.639*** (0.077)	3.297 (2.604)	4.273*** (0.078)	4.616** (2.226)
Constant	37.245*** (0.108)		37.861*** (0.106)		38.638*** (0.100)		39.515*** (0.099)	
Observations	3,362	3,362	3,362	3,362	3,554	3,554	3,554	3,554
R ²	0.132	0.080	0.132	0.085	0.122	0.044	0.122	0.052

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 1.F8: Classique panel regressions for female heads of household sample

<i>Dependent variable: Labor market time</i>								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Electricity	12.513*** (0.098)	7.215*** (2.164)	12.306*** (0.093)	8.109*** (2.228)	11.340*** (0.099)	8.742*** (2.514)	12.920*** (0.092)	11.987*** (2.425)
Age	-0.161*** (0.004)	-0.217*** (0.077)	-0.149*** (0.004)	-0.134* (0.080)	-0.204*** (0.004)	-0.212*** (0.081)	-0.191*** (0.004)	-0.172** (0.087)
HH size	0.521*** (0.036)	0.592 (0.740)	0.550*** (0.033)	1.037 (0.745)	0.477*** (0.036)	1.383* (0.793)	0.289*** (0.034)	1.782** (0.844)
Nb. Children (-13)	-1.540*** (0.049)	-1.621* (0.957)	-1.269*** (0.046)	-1.295 (1.011)	-1.578*** (0.047)	-1.827* (1.021)	-1.577*** (0.044)	-1.638 (1.087)
Education of Head	0.139*** (0.007)	0.189 (0.132)	0.184*** (0.007)	0.278** (0.141)	0.224*** (0.008)	0.157 (0.154)	0.268*** (0.007)	0.314* (0.166)
Rooms (pc)	-1.483*** (0.123)	-3.800 (2.303)	-0.832*** (0.116)	-3.739 (2.573)	-3.855*** (0.144)	-1.669 (3.235)	-4.692*** (0.137)	1.349 (3.577)
Domestic Help	4.885*** (0.240)	15.531* (8.382)	3.419*** (0.215)	4.644 (6.473)	5.492*** (0.211)	1.585 (7.277)	5.607*** (0.198)	10.889 (7.167)
Constant	36.102*** (0.227)		33.495*** (0.216)		40.893*** (0.233)		40.693*** (0.221)	
Observations	826	826	826	826	813	813	813	813
R ²	0.185	0.118	0.186	0.103	0.216	0.094	0.217	0.148

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 1.F9: Analysis of inequality of time allocation*Dependent variable: difference in absolute value of time used in each activity between the head of household and his or her spouse*

	Labor market time				Home time				Leisure time	
Electricity	7.557** (3.277)	4.402 (3.725)	3.574 (5.307)	1.099 (3.921)	0.310 (0.999)	0.409 (1.030)	-1.321 (1.060)	-1.751* (0.995)	2.376* (1.228)	1.913 (1.368)
Age	-0.239* (0.127)	-0.005 (0.115)	0.128 (0.142)	0.071 (0.196)	-0.113*** (0.028)	-0.153*** (0.028)	-0.177*** (0.027)	-0.124*** (0.032)	-0.021 (0.045)	-0.096** (0.043)
HH size	1.571 (1.093)	0.212 (1.243)	-1.823 (1.599)	2.366 (1.582)	-2.265*** (0.312)	-1.984*** (0.284)	-2.212*** (0.293)	-2.649*** (0.297)	-0.956** (0.475)	-1.233*** (0.424)
Nb. Children (-13)	-0.779 (1.489)	-0.938 (1.699)	2.485 (2.222)	-2.225 (2.391)	3.051*** (0.396)	2.653*** (0.353)	2.965*** (0.384)	3.692*** (0.430)	1.182** (0.580)	0.889* (0.492)
Education of Head	0.120 (0.271)	-0.252 (0.289)	-0.047 (0.361)	0.931** (0.367)	0.034 (0.066)	0.019 (0.063)	0.185*** (0.071)	0.112 (0.071)	-0.082 (0.093)	-0.140 (0.092)
Rooms (pc)	5.067 (5.923)	0.072 (4.849)	-19.165** (7.794)	-11.019 (9.817)	-3.027** (1.504)	-2.752* (1.512)	-1.904 (1.757)	-5.298*** (1.753)	-0.329 (2.440)	-2.307 (2.370)
Domestic Help	7.651 (6.858)	-8.640 (8.846)	-2.494 (9.641)	-10.581 (12.253)	0.723 (2.191)	-3.578* (1.947)	-7.489*** (2.654)	-1.962 (2.382)	5.207 (3.793)	-3.772 (2.907)
Gender	10.269 (7.797)	11.786 (11.096)	47.892*** (16.288)	-4.841 (20.851)	0.848 (3.434)	1.719 (3.122)	-1.156 (2.238)	-5.012* (3.043)	-0.262 (4.232)	0.531 (4.015)
Round	1	1	2	2	1	1	2	2	1	1
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	45	32	49	32	54	34	61	37	54	34
Observations	388	434	401	411	2,958	2,999	2,904	2,920	2,958	2,999
R ²	0.772	0.843	0.733	0.781	0.341	0.381	0.308	0.365	0.242	0.315
	Time for goods				Time for services				Leisure time	
Electricity	2.164 (1.361)	0.440 (1.281)	4.620*** (1.175)	-0.752 (1.310)	0.557 (2.818)	-1.632 (2.295)	1.538 (1.892)	4.164* (2.280)	-0.995 (1.416)	-2.062 (1.408)
Age	-0.019 (0.033)	-0.023 (0.033)	0.046 (0.039)	-0.037 (0.042)	-0.078 (0.054)	-0.191*** (0.067)	-0.173*** (0.058)	-0.294*** (0.065)	0.027 (0.039)	0.024 (0.046)
HH size	-0.288 (0.323)	-0.667 (0.406)	-0.645* (0.361)	0.795* (0.439)	-2.008*** (0.707)	-1.041 (0.672)	-2.096*** (0.658)	-0.495 (0.733)	-1.076*** (0.411)	-0.465 (0.456)
Nb. Children (-13)	0.228 (0.392)	0.605 (0.440)	1.255** (0.513)	-0.829 (0.517)	2.213*** (0.737)	1.901*** (0.705)	4.131*** (0.779)	1.926** (0.919)	1.563*** (0.567)	1.214** (0.583)
Education of Head	-0.016 (0.067)	-0.109 (0.091)	-0.052 (0.081)	0.088 (0.087)	0.023 (0.127)	-0.115 (0.117)	0.152 (0.123)	-0.292 (0.185)	0.084 (0.101)	0.011 (0.108)
Rooms (pc)	0.339 (1.616)	-0.431 (1.578)	3.118 (1.972)	3.327 (2.806)	-5.835** (2.837)	-6.729** (2.791)	-0.357 (3.075)	-2.028 (4.508)	1.148 (2.363)	-0.029 (2.550)
Domestic Help	-11.180*** (4.114)	1.229 (3.869)	-2.225 (7.151)	-33.468*** (6.338)	4.038 (6.944)	-6.549 (5.340)	-6.768 (4.620)	1.640 (9.716)	0.380 (3.699)	4.566* (2.666)
Gender	-1.477 (3.424)	3.232 (2.413)	0.976 (5.645)	-13.058*** (4.437)	-5.750 (7.968)	-10.018* (5.658)	-10.827* (5.850)	3.832 (6.561)	5.344 (4.495)	-9.471** (4.736)
Round	1	1	2	2	1	1	2	2	2	2
Cluster Process	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN
N Cluster	53	34	57	33	53	34	57	34	61	37
Observations	821	856	758	776	692	693	636	630	2,904	2,92
R ²	0.473	0.490	0.412	0.617	0.666	0.692	0.634	0.716	0.228	0.289

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 1.F10: Analysis of income inequality

<i>Dependent variable: Difference in absolute value between the head of the household and his ou her spouse</i>				
	Income			
Electricity	2,378.448 (1,745.725)	2,053.195 (7,938.031)	1,318.523 (1,724.048)	6,123.495*** (1,485.054)
Age	43.836 (55.918)	-142.928* (80.376)	-64.488 (68.446)	-184.684*** (55.289)
HH size	1,407.433** (685.459)	2,251.272 (2,385.673)	599.923 (642.085)	1,212.344* (707.114)
Nb. Children (-13)	-1,026.819 (708.909)	-3,330.831 (2,504.250)	-529.172 (809.496)	-953.640 (694.494)
Education of Head	113.907 (115.097)	148.576 (235.805)	245.620* (137.033)	269.309** (124.766)
Rooms (pc)	5,616.015** (2,782.605)	3,730.356 (8,247.689)	3,157.150 (2,518.963)	1,087.804 (4,431.714)
Domestic Help	7,920.820 (5,430.507)	558.176 (12,876.260)	32,738.230*** (9,927.554)	-7,414.150 (8,611.455)
Gender	-224.749 (5,188.094)	7,465.936 (5,752.356)	-2,719.716 (4,568.646)	5,463.087 (3,904.505)
Round	1	1	2	2
Cluster Process	Lat WE	Long SN	Lat WE	Long SN
N Cluster	50	30	53	32
Observations	775	800	642	633
R ²	0.663	0.343	0.618	0.818

*Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$*

Table 1.F11: Analysis of Adults time allocation

<i>Dependent variable:</i>		Labor market time	Home time	Leisure time	Time for goods	Time for services
Panel A: ≥ 18 years old						
All						
	Electricity	4.901*** (1.789)	0.207 (0.68)	-2.271* (1.22)	0.202 (0.616)	1.248* (0.703)
	N (sd)	1626 (52)	6274 (26)	6394 (27)	3117 (40)	3568 (42)
	R ² (sd)	0.49 (0.03)	0.39 (0.02)	0.28 (0.01)	0.22 (0.05)	0.46 (0.02)
Male						
	Electricity	5.548*** (1.648)	0.171 (0.584)	-5.056*** (1.308)	1.716** (0.796)	-0.473 (0.796)
	N (sd)	2055 (118)	5186 (24)	5283 (21)	2017 (62)	1346 (29)
	R ² (sd)	0.36 (0.02)	0.19 (0.03)	0.24 (0.02)	0.27 (0.06)	0.38 (0.03)
Female						
	Electricity	4.421** (2.142)	0.636 (0.772)	-0.984 (1.21)	-0.84 (0.512)	2.561*** (0.618)
	N (sd)	1018 (25)	6037 (16)	6141 (18)	3469 (23)	5297 (58)
	R ² (sd)	0.53 (0.04)	0.28 (0.01)	0.28 (0.01)	0.2 (0.04)	0.32 (0.01)
Panel B: 18-35 years old						
All						
	Electricity	3.293 (2.078)	0.308 (0.836)	-1.085 (1.376)	-0.031 (0.671)	1.187 (0.849)
	N (sd)	1207 (42)	4392 (17)	4581 (15)	2436 (24)	2479 (27)
	R ² (sd)	0.46 (0.04)	0.41 (0.02)	0.26 (0.02)	0.21 (0.04)	0.5 (0.02)
Male						
	Electricity	2.776 (2.076)	-0.63 (0.765)	-1.986 (1.663)	0.903 (1.054)	0.034 (0.865)
	N (sd)	1235 (60)	2894 (16)	3015 (14)	1274 (26)	803 (16)
	R ² (sd)	0.38 (0.02)	0.2 (0.04)	0.22 (0.02)	0.26 (0.06)	0.42 (0.05)
Female						
	Electricity	4.469 (2.788)	0.077 (0.992)	-0.252 (1.515)	-0.927 (0.631)	2.21*** (0.843)
	N (sd)	650 (14)	3526 (11)	3660 (10)	2227 (21)	3061 (42)
	R ² (sd)	0.53 (0.03)	0.3 (0.02)	0.26 (0.01)	0.22 (0.03)	0.33 (0.03)
Panel C: > 35 years old						
All						
	Electricity	6.23*** (2.168)	-0.286 (0.748)	-1.967 (1.346)	0.611 (0.803)	0.33 (0.745)
	N (sd)	1057 (18)	4723 (22)	4732 (22)	1943 (25)	2422 (32)
	R ² (sd)	0.52 (0.03)	0.34 (0.02)	0.33 (0.01)	0.24 (0.04)	0.41 (0.02)
Male						
	Electricity	5.932*** (2.296)	0.032 (0.724)	-2.569 (1.599)	2.034* (1.046)	-0.538 (1.267)
	N (sd)	1025 (51)	3187 (15)	3196 (14)	1039 (19)	627 (23)
	R ² (sd)	0.42 (0.05)	0.19 (0.02)	0.29 (0.02)	0.29 (0.06)	0.42 (0.03)
Female						
	Electricity	5.504** (2.411)	0.434 (0.855)	-1.659 (1.387)	-0.639 (0.736)	1.182* (0.674)
	N (sd)	533 (38)	3802 (23)	3805 (23)	1849 (15)	3159 (16)
	R ² (sd)	0.58 (0.03)	0.26 (0)	0.35 (0.01)	0.21 (0.03)	0.31 (0.01)

For all Panels, we include the control variables as long as the regression allows: Age, HH size, Nb. Children (-13), Education or/and Education of Head, Rooms (pc), Domestic Help. The control variable Gender is added only for the regressions of "All". The sample size may be different from one regression to another because of the first difference operator and the lack of data for some adults within the same household. For this we report the mean R-squared and the mean sample size and their standard deviations.

Table 1.F12: Analysis of children time allocation

<i>Dependent variable:</i>	Home time	Leisure time	Time for goods	Time for services
Panel A: ≤ 17 years old				
All				
Electricity	-2.12*** (0.519)	1.74** (0.791)	-1.524*** (0.395)	-0.151 (0.298)
N (sd)	4685 (12)	4753 (6)	4138 (75)	3905 (72)
R ² (sd)	0.3 (0.02)	0.61 (0.01)	0.26 (0.02)	0.38 (0.01)
Male				
Electricity	-1.89*** (0.546)	1.631* (0.854)	-1.45*** (0.451)	-0.009 (0.261)
N (sd)	3407 (8)	3438 (11)	3026 (40)	2590 (33)
R ² (sd)	0.26 (0.02)	0.59 (0.01)	0.26 (0.02)	0.31 (0.02)
Female				
Electricity	-2.298*** (0.618)	1.462 (0.901)	-1.501*** (0.428)	-0.254 (0.371)
N (sd)	3351 (26)	3407 (23)	2934 (73)	3017 (73)
R ² (sd)	0.32 (0.01)	0.62 (0.01)	0.27 (0.02)	0.36 (0.01)
Panel B: 5-13 years old				
All				
Electricity	-2.093*** (0.494)	2.22*** (0.51)	-1.843*** (0.375)	-0.249 (0.248)
N (sd)	4193 (2)	4193 (2)	4191 (3)	4192 (2)
R ² (sd)	0.32 (0.02)	0.32 (0.02)	0.27 (0.02)	0.29 (0.01)
Male				
Electricity	-1.607*** (0.539)	1.722*** (0.561)	-1.664*** (0.454)	0.055 (0.23)
N (sd)	2832 (11)	2832 (11)	2832 (11)	2832 (10)
R ² (sd)	0.3 (0.02)	0.31 (0.02)	0.27 (0.02)	0.21 (0.01)
Female				
Electricity	-2.184*** (0.636)	2.188*** (0.654)	-1.676*** (0.43)	-0.514 (0.365)
N (sd)	2756 (17)	2756 (17)	2754 (19)	2755 (18)
R ² (sd)	0.34 (0.01)	0.34 (0.01)	0.27 (0.02)	0.3 (0.02)
Panel C: 14-17 years old				
All				
Electricity	-1.535* (0.828)	1.387 (1.266)	-0.171 (0.69)	0.64 (0.711)
N (sd)	2152 (11)	2246 (18)	1388 (64)	998 (53)
R ² (sd)	0.22 (0.02)	0.17 (0.01)	0.2 (0.03)	0.33 (0.03)
Male				
Electricity	-1.047 (0.994)	1.908 (1.789)	-0.032 (1.077)	0.628 (0.808)
N (sd)	1196 (5)	1232 (10)	762 (45)	298 (24)
R (sd)	0.19 (0.03)	0.17 (0.02)	0.2 (0.04)	0.47 (0.05)
Female				
Electricity	-1.348 (1.097)	-0.773 (1.736)	-0.885 (0.87)	1.12 (0.82)
N (sd)	1277 (16)	1340 (19)	809 (27)	861 (34)
R ² (sd)	0.19 (0.01)	0.16 (0.01)	0.21 (0.05)	0.23 (0.02)

For all Panels, we include the control variables as long as the regression allows: Age, HH size, Nb. Children (-13), Education or/and Education of Head, Rooms (pc), Domestic Help. The control variable Gender is added only for the regressions of "All". The sample size may be different from one regression to another because of the first difference operator and the lack of data for some children within the same household. For this we report the mean R-squared and the mean sample size and their standard deviations.

Table 1.F13: Analysis of children education

Dependent variable: Children Education delay (14-17)						
Cluster type		R1 - Lat WE	R1 - Long SN	R2 - Lat WE	R2 - Long SN	All
All						
Electricity		0.034 (0.037)	0.06 (0.039)	0.015 (0.034)	0.012 (0.036)	0.03 (0.036)
N (sd)		2266 (1)	2261 (1)	2229 (0)	2231 (0)	2247 (17)
R ² (sd)		0.44 (0.02)	0.45 (0.01)	0.41 (0.01)	0.41 (0.01)	0.43
Male						
Electricity		0.044 (0.055)	0.071 (0.056)	0.026 (0.051)	0.027 (0.046)	0.042 (0.052)
N (sd)		1243 (0)	1242 (0)	1222 (0)	1221 (0)	1232 (10)
R ² (sd)		0.51 (0.01)	0.47 (0.01)	0.43 (0.01)	0.42 (0.01)	0.46 (0.04)
Femal						
Electricity		0.016 (0.049)	0.094* (0.051)	0.045 (0.055)	-0.012 (0.057)	0.036 (0.053)
N (sd)		1362 (0)	1356 (0)	1322 (0)	1326 (0)	1342 (18)
R ² (sd)		0.45 (0.01)	0.46 (0.01)	0.46 (0.01)	0.43 (0.01)	0.45 (0.01)

For all regression, we include the control variables as long as the regression allows: Age, HH size, Nb. Children (-13), Education of Head, Rooms (pc), Domestic Help. The control variable Gender is added only for the regressions of line “All”. The sample size may be different from one regression to another because of the first difference operator and the lack of data for some children within the same household. For this we report the mean R-squared and the mean sample size and their standard deviations.

Table 1.F14: Analysis of labour market participation

<i>Dependent variable: Labour market participation</i>													
Model		LPM	LPM	LPM	LPM	Logit	Logit	Logit	Logit	Probit	Probit	Probit	Probit
Panel A: All the sample													
All	Electricity	0.0288** (0.0130)	0.0288** (0.0126)	0.0239* (0.0126)	0.0239** (0.0110)	0.130** (0.0591)	0.130** (0.0569)	0.105* (0.0564)	0.105** (0.0493)	0.0802** (0.0363)	0.0802** (0.0349)	0.0643* (0.0348)	0.0643** (0.0303)
	Obs	19,928	19,928	19,885	19,885	19,518	19,518	19,459	19,459	19,518	19,518	19,459	19,459
	R ² or Psd R ²	0.091	0.091	0.099	0.099	0.0555	0.0555	0.0634	0.0634	0.0552	0.0552	0.0631	0.0631
Male	Electricity	0.0558*** (0.0168)	0.0558*** (0.0179)	0.0424*** (0.0151)	0.0424** (0.0168)	0.245*** (0.0733)	0.245*** (0.0796)	0.183*** (0.0666)	0.183** (0.0743)	0.153*** (0.0454)	0.153*** (0.0490)	0.115*** (0.0412)	0.115** (0.0461)
	Obs	9,226	9,226	9,234	9,234	9,050	9,050	9,053	9,053	9,050	9,050	9,053	9,053
	R ² or Psd R ²	0.086	0.086	0.088	0.088	0.0536	0.0536	0.0564	0.0564	0.0533	0.0533	0.0561	0.0561
Female	Electricity	0.00578 (0.0150)	0.00578 (0.0146)	0.00706 (0.0149)	0.00706 (0.0139)	0.0287 (0.0723)	0.0287 (0.0706)	0.0329 (0.0701)	0.0329 (0.0656)	0.0183 (0.0439)	0.0183 (0.0426)	0.0199 (0.0426)	0.0199 (0.0396)
	Obs	10,702	10,702	10,651	10,651	10,468	10,468	10,406	10,406	10,468	10,468	10,406	10,406
	R ² or Psd R ²	0.065	0.065	0.059	0.059	0.0317	0.0317	0.0300	0.0300	0.0315	0.0315	0.0299	0.0299
Panel B: Head household													
All	Electricity	0.0515*** (0.0162)	0.0515*** (0.0185)	0.0269* (0.0159)	0.0269 (0.0162)	0.237*** (0.0804)	0.237*** (0.0908)	0.126 (0.0820)	0.126 (0.0829)	0.143*** (0.0479)	0.143*** (0.0543)	0.0777 (0.0485)	0.0777 (0.0499)
	Obs	7,338	7,338	7,362	7,362	7,338	7,338	7,362	7,362	7,338	7,338	7,362	7,362
	R ² or Psd R ²	0.185	0.185	0.212	0.212	0.145	0.145	0.168	0.168	0.146	0.146	0.168	0.168
Male	Electricity	0.0700*** (0.0181)	0.0700*** (0.0206)	0.0330* (0.0191)	0.0330* (0.0190)	0.332*** (0.0920)	0.332*** (0.104)	0.161 (0.101)	0.161 (0.0986)	0.201*** (0.0544)	0.201*** (0.0620)	0.102* (0.0598)	0.102* (0.0600)
	Obs	5,380	5,380	5,365	5,365	5,380	5,380	5,365	5,365	5,380	5,380	5,365	5,365
	R ² or Psd R ²	0.136	0.136	0.141	0.141	0.105	0.105	0.110	0.110	0.105	0.105	0.110	0.110
Female	Electricity	-0.0128 (0.0255)	-0.0128 (0.0267)	0.00228 (0.0278)	0.00228 (0.0347)	-0.0976 (0.129)	-0.0976 (0.136)	0.00383 (0.147)	0.00383 (0.181)	-0.0610 (0.0769)	-0.0610 (0.0808)	-0.00933 (0.0890)	-0.00933 (0.107)
	Obs	1,958	1,958	1,997	1,997	1,958	1,958	1,997	1,997	1,958	1,958	1,997	1,997
	R ² or Psd R ²	0.226	0.226	0.244	0.244	0.190	0.190	0.208	0.208	0.192	0.192	0.210	0.210
Panel C: Adults													
All	Electricity	0.0304** (0.0134)	0.0304** (0.0135)	0.0231* (0.0130)	0.0231* (0.0114)	0.129** (0.0585)	0.129** (0.0591)	0.0987* (0.0571)	0.0987** (0.0502)	0.0808** (0.0361)	0.0808** (0.0365)	0.0611* (0.0351)	0.0611** (0.0311)
	Obs	16,799	16,799	16,834	16,834	16,456	16,456	16,467	16,467	16,456	16,456	16,467	16,467
	R ² or Psd R ²	0.092	0.092	0.103	0.103	0.0583	0.0583	0.0680	0.0680	0.0583	0.0583	0.0681	0.0681
Male	Electricity	0.0540*** (0.0175)	0.0540*** (0.0188)	0.0343** (0.0142)	0.0343** (0.0160)	0.236*** (0.0773)	0.236*** (0.0839)	0.154** (0.0646)	0.154** (0.0726)	0.146*** (0.0474)	0.146*** (0.0515)	0.0954** (0.0394)	0.0954** (0.0447)
	Obs	7,740	7,740	7,777	7,777	7,590	7,590	7,615	7,615	7,590	7,590	7,615	7,615
	R ² or Psd R ²	0.075	0.075	0.074	0.074	0.0476	0.0476	0.0488	0.0488	0.0476	0.0476	0.0489	0.0489
Female	Electricity	0.00835 (0.0155)	0.00835 (0.0161)	0.0118 (0.0172)	0.0118 (0.0162)	0.0359 (0.0692)	0.0359 (0.0722)	0.0527 (0.0764)	0.0527 (0.0724)	0.0236 (0.0426)	0.0236 (0.0441)	0.0320 (0.0469)	0.0320 (0.0444)
	Obs	9,059	9,059	9,057	9,057	8,866	8,866	8,852	8,852	8,866	8,866	8,852	8,852
	R ² or Psd R ²	0.059	0.059	0.059	0.059	0.0300	0.0300	0.0321	0.0321	0.0300	0.0300	0.0324	0.0324
Panel D: Children													
All	Electricity	-0.0324** (0.0144)	-0.0324** (0.0120)	-0.0424*** (0.0132)	-0.0424*** (0.0118)	-0.486* (0.250)	-0.486** (0.199)	-0.561*** (0.203)	-0.561*** (0.182)	-0.233* (0.119)	-0.233** (0.0949)	-0.283*** (0.101)	-0.283*** (0.0887)
	Obs	3,129	3,129	3,051	3,051	3,062	3,062	2,992	2,992	3,062	3,062	2,992	2,992
	R ² or Psd R ²	0.201	0.201	0.164	0.164	0.0835	0.0835	0.101	0.101	0.0820	0.0820	0.102	0.102
Male	Electricity	-0.0314* (0.0187)	-0.0314** (0.0145)	-0.0296 (0.0249)	-0.0296 (0.0275)	-0.416 (0.280)	-0.416* (0.234)	-0.275 (0.264)	-0.275 (0.287)	-0.215 (0.138)	-0.215** (0.110)	-0.140 (0.138)	-0.140 (0.148)
	Obs	1,486	1,486	1,457	1,457	1,460	1,460	1,438	1,438	1,460	1,460	1,438	1,438
	R ² or Psd R ²	0.193	0.193	0.129	0.129	0.0790	0.0790	0.0604	0.0604	0.0771	0.0771	0.0602	0.0602
Female	Electricity	-0.0339 (0.0204)	-0.0339* (0.0175)	-0.0557*** (0.0139)	-0.0557*** (0.0151)	-0.548 (0.363)	-0.548* (0.308)	-1.137*** (0.333)	-1.137*** (0.367)	-0.249 (0.171)	-0.249* (0.150)	-0.548*** (0.161)	-0.548*** (0.174)
	Obs	1,643	1,643	1,594	1,594	1,602	1,602	1,554	1,554	1,602	1,602	1,554	1,554
	R ² or Psd R ²	0.216	0.216	0.208	0.208	0.104	0.104	0.164	0.164	0.103	0.103	0.165	0.165
Round		1	1	2	2	1	1	2	2	1	1	2	2
Cluster type		Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN	Lat WE	Long SN

For all regression, we include the control variables as long as the regression allows: Age, HH size,

Nb. Children (-13), Education or/and Education of Head, Rooms (pc), Domestic Help. The control variable Gender

is added only for the regressions of line "All". For probit and logit models, we present the coefficient, not the odds ratios or the marginal effect.

Table 1.F15: Robustness: Analysis at the household and head of household level

<i>Dependent variable:</i>		Labor market time	Home time	Leisure time	Time for goods	Time for services
Panel A: Household level						
All						
Electricity		4.498*** (0.873)	-0.675* (0.376)	-0.242 (0.647)	-1.06*** (0.269)	0.958*** (0.306)
N (sd)		4426 (31)	6602 (17)	6602 (17)	5994 (29)	6511 (20)
R ² (sd)		0.28 (0.03)	0.27 (0.02)	0.37 (0.02)	0.18 (0.02)	0.29 (0.02)
Male						
Electricity		4.195*** (0.972)	-0.688* (0.415)	-0.345 (0.732)	-1.256*** (0.302)	1.131*** (0.345)
N (sd)		3508 (13)	4781 (29)	4781 (29)	4372 (40)	4720 (29)
R ² (sd)		0.25 (0.03)	0.29 (0.02)	0.38 (0.02)	0.18 (0.03)	0.31 (0.02)
Female						
Electricity		5.434*** (1.908)	-1.432* (0.802)	1.089 (1.321)	-1* (0.519)	-0.106 (0.613)
N (sd)		940 (28)	1820 (18)	1820 (18)	1616 (14)	1790 (12)
R ² (sd)		0.39 (0.04)	0.25 (0.02)	0.33 (0.02)	0.18 (0.02)	0.24 (0.03)
Panel B: Household Heads						
All						
Electricity		7.436*** (1.577)	-0.994 (0.645)	-2.919** (1.159)	1.244 (0.772)	-0.76 (0.783)
N (sd)		2258 (78)	6601 (18)	6602 (17)	2590 (49)	2465 (19)
R ² (sd)		0.4 (0.04)	0.2 (0.02)	0.31 (0.02)	0.23 (0.04)	0.31 (0.04)
Male						
Electricity		6.542*** (1.662)	-0.285 (0.64)	-3.925*** (1.363)	1.283 (0.928)	-0.366 (0.856)
N (sd)		1998 (95)	4781 (30)	4781 (29)	1774 (57)	1257 (30)
R ² (sd)		0.35 (0.04)	0.18 (0.02)	0.28 (0.02)	0.24 (0.04)	0.37 (0.06)
Female						
Electricity		6.177 (3.783)	-0.982 (1.365)	0.699 (2.215)	0.104 (1.248)	0.306 (0.998)
N (sd)		325 (13)	1820 (18)	1820 (18)	826 (15)	1438 (44)
R ² (sd)		0.67 (0.05)	0.27 (0.02)	0.39 (0.02)	0.25 (0.04)	0.31 (0.02)

For all Panels, we include the control variables as long as the regression allows: Age, HH size, Nb. Children (-13), Education of Head, Rooms (pc), Domestic Help. The control variable Gender is added only for the regressions of "All". The sample size may be different from one regression to another because of the first difference operator and the lack of data for some adults within the same household. For this we report the mean R-squared and the mean sample size and their standard deviations.

Table 1.F16: Robustness: Time and Income Inequality Analysis

<i>Dependent variable: Difference in absolute value between the head of the household and his ou her spouse</i>						
Cluster type		R1 - Lat WE	R1 - Long SN	R2 - Lat WE	R2 - Long SN	All
Time allocation Inequality						
Labor market time						
	Electricity	6.304 (4.177)	5.075 (4.256)	1.208 (4.715)	1.34 (4.779)	3.482 (4.482)
	N (sd)	402 (13)	402 (13)	404 (14)	404 (14)	403 (14)
	R ² (sd)	0.75 (0.05)	0.77 (0.04)	0.75 (0.05)	0.77 (0.04)	0.76 (0.05)
Home time						
	Electricity	0.078 (1.025)	0.1 (1.023)	-0.809 (1.041)	-0.883 (1.052)	-0.379 (1.035)
	N (sd)	2963 (20)	2963 (20)	2918 (20)	2918 (20)	2940 (30)
	R ² (sd)	0.33 (0.03)	0.34 (0.03)	0.33 (0.03)	0.33 (0.03)	0.33 (0.03)
Leisure time						
	Electricity	1.468 (1.392)	1.44 (1.393)	-1.829 (1.442)	-1.544 (1.447)	-0.116 (1.419)
	N (sd)	2963 (20)	2963 (20)	2918 (20)	2918 (20)	2940 (30)
	R ² (sd)	0.26 (0.04)	0.27 (0.03)	0.25 (0.04)	0.26 (0.03)	0.26 (0.04)
Time for goods						
	Electricity	0.378 (1.16)	0.719 (1.21)	1.087 (1.252)	0.921 (1.302)	0.776 (1.231)
	N (sd)	836 (12)	836 (12)	778 (15)	777 (15)	807 (33)
	R ² (sd)	0.46 (0.05)	0.46 (0.06)	0.48 (0.05)	0.48 (0.06)	0.47 (0.06)
Time for services						
	Electricity	0.351 (2.255)	0.075 (2.259)	1.483 (2.033)	1.431 (2.13)	0.835 (2.169)
	N (sd)	680 (16)	680 (16)	625 (17)	625 (17)	653 (32)
	R ² (sd)	0.62 (0.06)	0.64 (0.05)	0.67 (0.05)	0.67 (0.05)	0.65 (0.06)
Income Inequality						
Income						
	Electricity	0.463** (0.231)	0.452** (0.222)	0.542** (0.261)	0.533* (0.297)	0.498** (0.253)
	N (sd)	1827 (18)	1827 (18)	1931 (24)	1931 (24)	1879 (56)
	R ² (sd)	0.70 (0.17)	0.70 (0.17)	0.69 (0.25)	0.64 (0.26)	0.68 (0.22)

For all regression, we include the control variables as long as the regression allows: Age, HH size, Nb. Children (-13), Education of Head, Rooms (pc), Domestic Help. The control variable Gender is added only for the regressions of line “All”. The sample size may be different from one regression to another because of the first difference operator and the lack of data for some children within the same household. For this we report the mean R-squared and the mean sample size and their standard deviations.

Table 1.F17: Comparison of assumptions and results

		Time allocation									Education		
		Labor market			Domestic/Home			Leisure					
		Hyp.	Est.	Verified?	Hyp.	Est.	Verified?	Hyp.	Est.	Verified?	Hyp.	Est.	Verified?
Children	Boys	-		Not est.	- or null	-	Yes	+	+	Yes	+	Non-sign.	No
	Girls	-		Not est.	- or null	-	Yes	+	+	Yes	+	Non-sign.	No
Household head	Men	+	+	Yes	- or null	Non-sign.	Yes	+/-	-	Yes			
	Women	+	Non-sign.	No	- or null	Non-sign.	Yes	+/-	-	Yes			
Adults	Men	+	+	Yes	-	Non-sign.	No	+	-	No			
	Women	+	+	Yes	-	Non-sign.	No	+	-	No			

Note: -: statistically negative, + statistically positive, +/- statistically positive or negative, Not Est.: when the coefficient has not been estimated, - or null: when the coefficient can be significantly negative or insignificant, No: when the hypothesis is not verified, Yes: if the hypothesis is verified, Non-sign.: Not statistically significant

2

Women's Empowerment in Agriculture and Household Food Security: Evidence from Rural Ethiopia¹

Abstract: This chapter examines the link between women's empowerment in agriculture and household food security in dual-adult rural households in Ethiopia, in 2014. Factor and cluster analyses are used to construct three household types based on women's ownership and management of productive assets (plots, livestock) and decision-making during and after production. Food security is measured using objective indicators of dietary diversity and caloric intake based on 7-day recall food consumption data and subjective data about food shortage over the past year. Parametric regression results show higher women empowerment in agriculture is associated with more diverse household diets, higher caloric intake, and a lower likelihood of the household worrying about not having enough food. The finding about dietary diversity is primarily driven by the consumption of more diverse purchased foods, which may be explained by women's role in food markets and preparation in general and in informal food markets that are widespread in rural areas. Our findings are consistent with previous research that shows positive effect of women's engagement in and control over agricultural production on household food security and child nutrition. We highlight the need for addressing gender inequalities in access to and control over productive agricultural resources and decision-making. This is especially important in patriarchal systems like those in Ethiopia where women have limited land rights and complex patterns of livestock ownership have been documented that are mediated by gender.

Keywords: Women; Empowerment; Agriculture; Food; Security; Ethiopia

JEL Codes: Q12, Q18, I38, J16, O15, O55

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2.1 Introduction

Agriculture is a cornerstone of Ethiopia's economy, accounting for approximately 40% of GDP, 80% of exports, and employing 75% of the workforce (USAID, 2021; Food and Agriculture Organization and Organisation for Economic Co-operation and Development, 2016). This proportion is significantly higher than the Sub-Saharan African average, where agriculture contributes around 15% of GDP and employs 50% of the population (Food and Agriculture Organization and Organisation for Economic Co-operation and Development, 2016; International Labour Organization, 2020). Ethiopia has one of the highest agricultural growth rates in Africa, exceeding 6% annually, making it a focal point for initiatives aimed at modernizing agriculture and reducing rural poverty (AfDB, 2024). Despite these advancements, the sector relies primarily on smallholder farmers, and productivity remains low due to outdated farming practices, limited irrigation, and soil degradation (USAID, 2021).

The Ethiopian government, with support from international organizations such as USAID, the World Bank, and IFC, has implemented ambitious programs to address these challenges (USAID, 2021; World Bank, 2024a; International Finance Corporation, 2024). Initiatives such as the Sustainable Agricultural Development and Climate Resilience Program (PASIDP) and the Feed the Future initiative focus on improving productivity, strengthening food security, and promoting climate resilience (USAID, 2023, 2021, 2018). Furthermore, Ethiopia ranks among the top three cereal producers in Africa, but its yields per hectare remain low compared to other regions, highlighting significant room for improvement (Zerfu et al., 2024; AfDB, 2024).

Women play a pivotal role in Ethiopia's agricultural sector, mirroring their importance across Sub-Saharan Africa, where they constitute around 50% of the agricultural workforce and contribute 60–80% of household food production (African Development Bank Group, 2015; United Nations, 2014). In Ethiopia, women face significant barriers to accessing productive resources, such as land, agricultural innovations, and financial services (International Trade Administration, 2024; USAID, 2023, 2018). In this part of the region in Africa, only about 10% of women own agricultural land, despite their substantial contribution to agricultural labor and

wealth ([United Nations, 2018](#)). These structural and cultural challenges constrain women's ability to maximize their potential in the sector.

Empowering women in agriculture can have transformative impacts on household food security and well-being. Improved access to resources and decision-making can enhance total production, diversify dietary intake, and better allocate income between food and non-food items ([Doss and Quisumbing, 2020](#); [Quisumbing et al., 2019](#); [Malapit et al., 2019](#); [Dasgupta and Mani, 2015](#)). Evidence from Ethiopia and other regions highlights the positive association between women's empowerment and household outcomes, such as child nutrition and dietary diversity. For instance, women-led home gardening initiatives in Bangladesh and Kenya have improved dietary diversity and child nutrition ([Talukder et al., 2000](#); [Chepkirui, 2019](#)). Similarly, increased control over livestock by women in rural Uganda and Nepal has led to greater consumption of animal-source foods and improved maternal and child nutrition ([Azzarri et al., 2015](#); [Malapit et al., 2013](#)).

Ethiopia's agricultural transformation, coupled with the central role of women in the sector, provides a unique context to analyze how women's empowerment can influence household food security and well-being. By combining Ethiopia's distinct agricultural challenges and opportunities with insights from Sub-Saharan Africa, this study contributes to a deeper understanding of the interplay between gender, agricultural development, and food security in a rapidly changing economy.

This study examines the association between women's empowerment and household food security using survey data from rural Ethiopia. Women's empowerment is measured based on sex-disaggregated data about ownership of agricultural plots and livestock, decisions about sale of harvest and use of sales, and decisions about the sale of livestock and by-products. About 47% of plots and 72% of animals in our sample are jointly (men and women) owned while women-only ownership accounts for just about 5%. Controlling for several confounding factors, higher women's empowerment is associated with more diverse household diets, higher caloric intake, fewer months of food shortages, and a lower likelihood of worrying about not having enough food. The positive link between dietary diversity and women's empowerment is driven by the consumption of more diverse purchased foods versus the consumption of more diverse food.

The remainder of this chapter is structured as follows. The literature review is summarized in Section 2.2. Section 2.3 describes the data and the methodology. The results are presented in Section 2.4. Section 2.5 presents robustness check, and Section 2.6 concludes.

2.2 Literature review

Female-headed households in Ethiopia tend to have lower agricultural productivity compared to male-headed households (Aguilar et al., 2015). There is a 23% gender gap in agricultural productivity between men and women in the country (World Bank, 2014). Studies by Mulugeta and Amsalu (2014) and Tsegaye et al. (2012) suggest that rural women in Ethiopia lack decision-making power in purchasing and selling farm equipment, land preparation, and seed production. Additionally, according to of Rural Reconstruction (2003), Ethiopian women face obstacles in participating in educational programs compared to men and are often burdened with tasks such as weeding and childbirth.

The gender gap in agricultural productivity can be attributed to differences in men's and women's access to and control over resources. Although women's land ownership and access have improved in Ethiopia through the land reform program, female household heads generally have smaller farm sizes than their male counterparts (Teklu, 2005). Moreover, land access rights vary depending on women's marital status (Torkelsson and Tassew, 2008). Women in Ethiopia also face disadvantages in accessing agricultural advice and services, as well as credit from banks and cooperatives, leading to income differentials (World Bank, 2014). Overall, key constraints include limited access to and control over productive resources, income, markets, labor, information, and education for women.

Despite facing limitations, women farmers in Ethiopia play a significant role in agricultural production. Women represent more than 40% of the agricultural labor force in the country and head about 25% of national farm households (Tiruneh et al., 2023). However, due to factors such as limited access to inputs like fertilizer, they produce 35% less than male farmers (USAID, 2023). Mahmud et al. (2012) argue that increasing women's available resources, such as income, can improve their bargaining power within the household and promote gender equality. Therefore, it

is crucial to acknowledge women's contributions to agricultural production and food security in Ethiopia and undertake research aimed at improving their empowerment and access to resources.

2.3 Data and methodology

In this section, we present the data and the main variables, outline the stylized facts, and describe the methodology that we will further use.

2.3.1 Data and variables

Data is collected based on surveys. This survey-based data was collected in 2014 as part of a sustainable intensification program called Africa Research In Sustainable Intensification for the Next Generation (Africa RISING), known as Ethiopia Africa RISING Baseline Evaluation Survey (ARBES). About 500 households were surveyed covering four regions (Amhara, Oromia, SNNP, and Tigray) and eight villages ([International Food Policy Research Institute, 2016](#)). We restrict the sample to 394 ARBES married households for which data is fully available. We focus on married households and do not consider women-only households as we aim to investigate women's empowerment. To construct women's empowerment scores we use sex-disaggregated data collected based on eight survey questions summarized in Appendix A, Table 2.A1.

These questions cover the following domains - plot-level ownership and decision-making about planting and use of inputs; plot-level decision about harvest sales and use of sales revenue; ownership and management of different livestock; and decisions about sale of livestock and by-products ([Mulema et al., 2017](#); [Mulugeta and Amsalu, 2014](#)). Responses to each survey question are coded as head, spouse, joint (head and spouse), and others that we recode as women-only (i.e., female heads that account for only 5% or spouses of male heads), men-only (i.e., male heads or spouses of female heads), and joint based on data from the household roster. Productive resources in Ethiopia, especially large animals, often are managed by the household head, often male, even when they are reported to be jointly owned. Similarly, even when women are sole owners of assets such as small animals, men often have more control over income ([Fafchamps and Quisumbing, 2002](#)).

Analyzing plot and animal-specific sex-disaggregated data about ownership as

well as decision-making allows us to capture nuanced gender dynamics in Ethiopia's complex mixed farming systems. To account for variations across plots and animal types within households and the dominance of mixed farming systems in Ethiopia, we compute the mean share of women-only, men-only, and joint arrangements at the household level with values ranging from 0 to 100. For example, in a household with five plots of which two are men-only, one is women-only, and two are joint, men-only, women-only, and joint plot management indicators will have a score of, respectively, 40%, 20%, and 40%. Given the dominance of joint arrangements across the eight domains (46%-77%) and the relatively small incidence of women-only cases (3%-10%), we combine joint and women-only into one group by summing scores for joint and women-only cases across the eight domains (see Appendix A Table 2.A2 for summary).

Our main outcome is household food security which we measure based on data on the quantity of foods consumed inside the household and the household's perceptions about food shortages. Seven-day recall food consumption data are used to construct household dietary diversity score (HDDS) based on 12 food groups as well as an indicator capturing whether household caloric intake is above the minimum dietary energy requirement (MDER). Since ARBES disaggregates food sources (own produced, purchased, gifted), we also compute HDDS separately for own consumed and purchased foods to examine possible pathways from empowerment and food security. Two more subjective indicators are constructed based on whether the household was worried about food shortage in the previous week and the number of food shortage months in the past year and during lean months of June to September 2013. This mix of food security indicators allows us to capture the state of food security over different periods as well as using objective and subjective indicators.

In addition, we construct several conditioning variables including household characteristics (age of the head, highest schooling attended by male and female members, and dependency ratio²), assets (land size, livestock, indices for durable agricultural and non-agricultural assets and dwelling condition³), inputs, and harvest value. The

²The ratio of the number of individuals assumed to be "dependent" on others for their daily lives - young people (under 15) and the elderly (over 65) - to the number of individuals capable of assuming this burden.

³Together, these two indices provide a more comprehensive assessment of household wealth by distinguishing assets based on their nature (agricultural or non-agricultural). They are calculated

GPS location of ARBES households is used to process precipitation data from Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) (Funk et al., 2015) that has 0.05° resolution. We construct total precipitation and precipitation variability at household level for the main rainy season of May – September 2013.

2.3.2 Stylized facts

As shown in Appendix A Table 2.A3, the correlations concerning women's empowerment scores across the eight domains range between 0.3 and 0.9. Considering this, we use non-supervised machine learning techniques-clustering by K-medians (Paul, 2000) – and dimension reduction technique Principal Component Analysis (PCA) - to identify farm types (Lever et al., 2017). PCA helps to transform possibly correlated data into a smaller number of orthogonal variables known as principal components (PC) that capture the variance in our data. Following previous studies (Partridge and Jabri, 2000), we pick the first three PCs that explain around 80% of the variation and apply K-medians partition clustering to construct three empowerment-based farm types consisting of households. The three farm types are defined as having high (H), moderate (M) and low (L) women's empowerment (WE) defined here as HWE, MWE, and LWE, respectively.

Using the women's empowerment scores across the eight domains, we notice that the three farm types have an average empowerment score of 90% (HWE), 67% (MWE) and 16% (LWE) with domain-specific scores shown in Appendix Figure 2.B1. The LWE group has exceptionally small (<5%) joint plot ownership and decision-making even when it has modest joint livestock ownership. This group has a relatively high joint livestock management despite having very low joint livestock ownership. This is expected given that Ethiopian women are dominant in livestock management and husbandry practices including feeding, management of vulnerable animals such as calves and small ruminants, cleaning of barns, dairy-related activities, collection and making of dung cakes, and sale of egg/poultry (Kinati

through factor analysis on the endowments in livestock, agricultural, and others non agricultural asset to obtain an overall score for agricultural assets. The non-agricultural wealth index assesses household non-agricultural wealth, focusing on housing conditions (such as quality of materials and access to water and electricity) and durable non-agricultural assets (including household appliances and vehicles). In parallel, the agricultural wealth index measures agricultural wealth by considering livestock value and quantity, durable agricultural assets (tools and equipment). We exclude the size of operated land.

and Mulema, 2018). The HWE group operates larger land size, has a higher stock of durable agricultural and non-agricultural assets, grows fewer crops, owns more livestock (TLU), and has higher earnings from the sale of livestock and by-products relative to the LWE group. On the other hand, the LWE group that operates smaller farm uses more inputs per hectare supporting previous findings about inverse farm size-input use relationship in Africa (Abay et al., 2022; Sheahan and Barrett, 2017).

2.3.3 Parametric analyses of food security and women's empowerment

To examine the association between food security and women's empowerment the linear model in Equation 2.1 is estimated using OLS.

$$Y_h = \alpha + \beta_h HWE_h + \beta_m MWE_h + \Theta'Z + \epsilon_h \quad (2.1)$$

where h indexes households, Y is one of the food security indicators discussed above; HWE and MWE are as defined before, with LWE used as a reference category. Z is a matrix of conditioning variables, and ϵ is the model error term assumed to be i.i.d. Variables in Z include several socio-demographic and economic variables such as the age of the household head, years of education of the head and his/her spouse, dependency ratio, land size, asset indices, agricultural inputs used per hectare, on-farm diversity indicators (number of unique crop produce and number of unique livestock types owned), travel time to the closest weekly market, and two precipitation indicators discussed above. We progressively increase the elements of Z as a sensitivity check but report results from the full model in the main text. Standard errors from all regressions are clustered at the village level.

2.4 Results and discussion

Bivariate associations show women's empowerment score to have a positive association with dietary diversity from purchased food and food security and a negative association with subjective food shortage (Figure 2.1). We recall that a zero score for women's empowerment indicator corresponds with households where men are the sole owners and decision makers across the eight dimensions while higher scores are related to higher asset ownership and decision-making by women either jointly

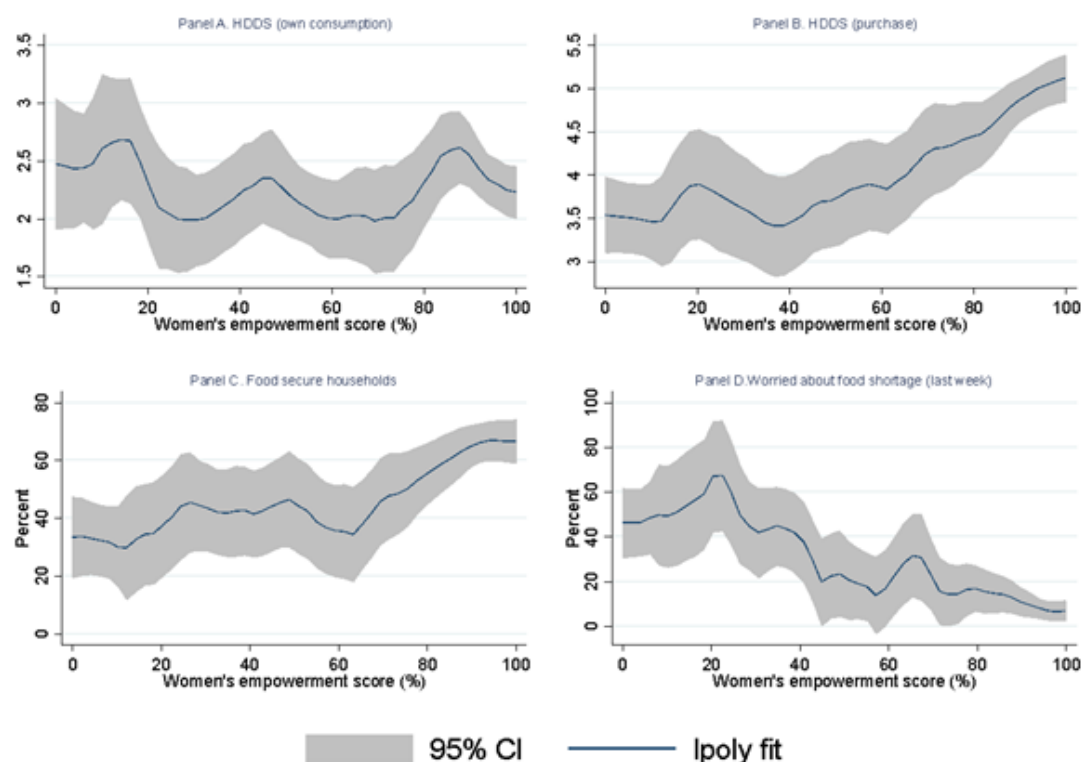


Figure 2.1: Non-parametric associations between women's empowerment and food security

or solely.

The analysis of household food expenditure patterns by farm types shows that HWE households have a higher expenditure share on cereals relative to LWE households. While the share of animal-source foods is relatively low across the board, HWE households spend a relatively higher share of total expenditure on purchased food on animal-source foods like meat, poultry, fish, and eggs as well as on fruits and vegetables (Figure 2.B2). Consistent with previous findings, almost all of the milk and dairy consumption comes from own production highlighting the importance of livestock ownership for enhancing household nutrition in rural areas (Abegaz et al., 2018; Hoddinott et al., 2015).

Multivariate analysis results confirm patterns from the descriptive summary where both HWE and MWE households have more diverse diets (1-1.3 food group), more diverse purchased foods (+0.86 - 0.96), higher likelihood of being food secure (26 - 30 percentage point-pp), less likely to worry about food shortage (15-24 pp) relative to LWE households. HWE households also experience months of food

shortage during the lean season (about two weeks) relative to LWE households.

Table 2.1: Associations between women’s empowerment and household food security

	HDDS - all foods	HDDS own duced	- HDDS pro- purchased	- Food secure	Worried food (past week)	about shortage (past year)	Months food shortage (lean season)
High women’s empowerment	1.01** (0.35)	0.43 (0.28)	0.86** (0.30)	30.28*** (6.64)	-24.63*** (5.22)	-0.61 (0.38)	-0.44** (0.14)
Moderate women’s empowerment	1.37*** (0.31)	0.87** (0.36)	0.96*** (0.22)	25.73* (11.23)	-15.04* (6.58)	-0.15 (0.25)	-0.11 (0.16)
Number of observations				380			
R-squared	0.395	0.400	0.434	0.150	0.265	0.235	0.200

Note: Reported are OLS coefficient estimates and robust standard errors (in parentheses). HDDS stands for household dietary diversity score. Low women’s empowerment group is the omitted category. All models control for demographic characteristics, variable agricultural inputs, land size, durable agricultural and non-agricultural assets, total precipitation, and their viability. See Appendix A Table 2.A4 -cont’d in 2.A5 and 2.A6 - for a full list of control variables. * p<0.1, ** p<0.05, *** p<0.01.

These findings are consistent with previous results where, for example, control over income by Hondurans women is positively associated with household dietary diversity and negatively associated with the likelihood of experiencing moderate to severe food insecurity (Larson et al., 2019). A similar finding was reported in Bangladesh where higher intra-household bargaining power, measured by a household-level panel survey and a review of ethnographic literature, is associated with higher calorie availability and dietary diversity in households (Sraboni et al., 2014).

2.5 Robustness

Table 2.2: Food Security - Global Indicator

VARIABLES	(1)	(2)	(3)
	Global Food Security Index		
High women empowerment	1.68*** (0.22)	1.10*** (0.21)	1.22*** (0.20)
Moderate women empowerment	0.83 (0.52)	0.82** (0.30)	1.07*** (0.27)
Observations		394	
R-squared	0.167	0.396	0.407

Robust standard errors in parentheses. Low women's empowerment group is the omitted category.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

To gain a broader understanding of the effects of women's empowerment on food security, we developed a more generalized measure of food security (Global Food Security Index). We used Principal Component Analysis (PCA) to reduce the number of food security variables into a more compact dimension. Based on the elbow criterion (eigenvalue > 1), three components emerged, explaining approximately 80% of the information contained in the seven food security variables. The first component, which accounts for 41.46% of the total variability, is strongly correlated with all the variables (see Table 2.A7 in Appendix A). This component contrasts individuals with a higher level of food security (high values of HDDS – all foods, HDDS – own produced, HDDS – purchased, and higher food security, with very low values for fear of food shortages and the number of months of food insecurity) with

individuals experiencing lower food security (low values for the same variables, but very high values for fear of food shortages and the number of months of food insecurity)—see Figure 2.B3 and Table 2.A7 in Appendix A. We retained this component as it provides a comprehensive overview of food security in our sample, while the other components focus on more specific aspects of food security.⁴

The results are presented in Table 2.2. The findings confirm our initial results: there is a positive association between women’s empowerment and food security. These results appear robust under this broader measurement of food security and hold across different model specifications (columns 1, 2, and 3).

2.6 Conclusion

Gender inequalities in ownership of agricultural production resources, services, and decision-making are a common phenomenon across most countries of the developing world. Despite these constraints, women make significant contributions across the crop and animal production value chains thereby enhancing household food security through consumption of own-produced goods, higher household purchasing power, and intra-household decisions about resource allocations. This study examines the link between women’s empowerment and household food security in rural Ethiopia where empowerment is defined based on sex-disaggregated data about productive agricultural asset ownership as well as decision-making about the agricultural sale and use of sales revenue.

We find a strong positive association between women’s empowerment, household dietary diversity, caloric intake, and subjective food security controlling for several confounding factors. The positive association between empowerment and dietary diversity is driven by consumption of more diverse purchased foods. These findings highlight the need for interventions that empower rural women by enhancing the ownership of resources such as land and livestock and their decision-making about resource allocations. Our results are robust to different specifications and different measures of food security.

This requires targeted interventions that tackle deep-rooted institutional and

⁴The second component appears to reflect individuals with an intermediate level of food security (moderate correlations), with specific characteristics, notably high values for HDDS – own produced and the number of months of food insecurity. The third component simply contrasts individuals with high HDDS – own produced values and those with very low HDDS – purchased values.

cultural norms as well as practices that limit women's asset ownership, their access to improved agricultural innovations, and their ability to effectively participate in decision-making. For example, the patriarchal land ownership systems that are dominant in many African countries imply that women often must depend on men to access the most important agricultural asset. In addition, even when women access land, they often operate lower-quality fields. As such, more equitable land policy reforms will go a long way to strengthen rural women's land rights and tenure security.

This study has several notable limitations. A primary constraint is the limited temporal dimension, which restricts our ability to observe dynamic changes in the relationship between women's empowerment and household food security over time. Additionally, there is the potential for measurement bias in the indicators used to assess both women's empowerment and household food security. These constructs are inherently multi-dimensional and context-specific, so the chosen variables may not fully capture the nuances of empowerment or accurately reflect food security across diverse household contexts.

Future research could benefit from alternative measurement frameworks or the integration of qualitative data, as this would enable a more comprehensive understanding of the influence of empowerment on food security. Such approaches would also ensure that the selected variables are more aligned with the lived experiences and challenges encountered by women in various settings. Furthermore, an exploratory path for future studies could involve non-parametric analysis techniques, particularly using machine learning methods. This approach could reveal complex variable combinations, conditioned by varying levels of women's empowerment, that contribute to distinct levels of food security. Such an analysis could offer deeper insights into the factors driving food security outcomes and enhance our understanding of how women's empowerment contributes to these outcomes.

APPENDIX

A Tables

Table 2.A1: Sex-disaggregated survey questions

No.	Domain	Question
1	Crop	Who in the household owned the parcel?
2	Crop	Which family member had main responsibility for deciding which crop should be planted on plot?
3	Crop	Which family member had main responsibility for deciding on resource allocation on plot (e.g., labor use)?
4	Crop	Which family member had main responsibility regarding the sale of harvest from plot (e.g., where and how much to sale)?
5	Crop	Which family member had the main responsibility for deciding how revenue from sale of crop(s) grown on plot was used?
6	Livestock	Which household member owns (most of) animal type?
7	Livestock	Which household member took care of animal type (most of the time)?
8	Livestock	Which household member made decisions regarding the sale of animal type and/or by- products?

Table 2.A2: Sex-disaggregated summary of resource ownership and decision making

	(1)		(2)		(3)	
	Men-only		Women-only		Joint	
	Mean	SD	Mean	SD	Mean	SD
Parcel ownership	27.3	37.7	4.42	15.8	46.8	42.8
Plot level planting decisions	36.8	47.7	3.05	16.6	58.8	48.7
Plot level resource allocation decisions	39.3	48.3	3.05	16.6	56.3	49.0
Plot level sale decisions	28.7	44.7	3.37	17.4	66.7	46.7
Plot level decision about use of sales revenue	22.8	40.3	4.02	16.5	71.9	44.2
Livestock ownership	21.7	38.4	6.64	20.8	71.8	41.6
Livestock management	14.3	32.0	9.99	23.7	52.4	47.3
Sale of livestock and by-products	16.8	35.0	6.61	21.3	77.4	38.7
Observations	394					

Note: SD stands for standard deviation. The sum of percentages across the three groups does not add up to 100 due to the exclusion of "other" decision makers for whom sex-disaggregation is not possible.

Table 2.A3: Pair-wise correlations among the dimensions of women's empowerment

	1	2	3	4	5	6	7
1 Share of women owned parcels sole\joint (%)	1						
2 Share of plots with planting decisions made by women sole\joint (%)	0.62***	1					
3 Share of plots with resource allocation decisions made by women sole\joint (%)	0.58***	0.91***	1				
4 Share of plots with sales decisions made by women sole\joint (%)	0.60***	0.80***	0.78***	1			
5 Share of plots with use of sales decisions made by women sole\joint (%)	0.60***	0.71***	0.70***	0.84***	1		
6 Share of livestock managed by women sole\joint (%)	0.28***	0.42***	0.44***	0.26***	0.32***	1	
7 Share of livestock owned by women sole\joint (%)	0.60***	0.63***	0.57***	0.63***	0.62***	0.35***	1
8 Share of livestock and by-products sale decisions made by women sole\joint (%)	0.47***	0.58***	0.54***	0.57***	0.62***	0.49***	0.72***

Note: Columns represent survey questions shown in the corresponding row number.

Table 2.A4: Associations between women's empowerment and household food security

	HDDS - all foods			HDDS - own produced			HDDS - purchased		
High women empowerment	1.30*** (0.29)	0.67* (0.32)	1.01** (0.35)	-0.24 (0.21)	-0.39* (0.20)	0.43 (0.28)	1.64*** (0.31)	1.03** (0.34)	0.86** (0.30)
Moderate women empowerment	0.41 (0.54)	0.53 (0.38)	1.37*** (0.31)	0.10 (0.40)	0.15 (0.34)	0.87** (0.36)	0.38 (0.49)	0.49 (0.31)	0.96*** (0.22)
Household head age (years)		-0.01 (0.01)	-0.01 (0.01)		0.03 (0.01)	0.01 (0.01)		-0.03*** (0.01)	-0.02** (0.01)
Female head/spouse education (years)		-0.01 (0.06)	-0.00 (0.05)		-0.00 (0.03)	0.00 (0.03)		-0.00 (0.05)	-0.01 (0.03)
Male head/spouse education (years)		0.02 (0.02)	0.02 (0.02)		0.06*** (0.01)	0.01 (0.02)		-0.01 (0.03)	0.03 (0.02)
Dependency ratio		0.08 (0.12)	0.14 (0.08)		0.12 (0.10)	0.11 (0.08)		0.03 (0.13)	0.11 (0.09)
Operated land (ha)		0.13** (0.04)	0.09 (0.05)		-0.02 (0.04)	0.01 (0.02)		0.13** (0.05)	0.07 (0.05)
Durable agr. assets (except land) (index)		0.13 (0.13)	0.32** (0.13)		0.24*** (0.06)	0.14 (0.09)		0.03 (0.12)	0.37** (0.12)
Durable non-agr. assets (index)		0.62*** (0.16)	0.39*** (0.10)		0.26 (0.19)	0.25* (0.12)		0.64*** (0.12)	0.39*** (0.07)
Ln fertilizers used (ka/ha)			0.10 (0.06)			0.09 (0.05)			-0.01 (0.07)
Ln manure used (kg/ha)			-0.07** (0.03)			0.01 (0.02)			-0.06 (0.04)
Ln improved seeds purchased (Birr/ha)			0.04 (0.02)			0.01 (0.02)			0.03 (0.03)
Ln cost of hired labor (Birr/ha)			0.04* (0.02)			0.01 (0.01)			0.02 (0.02)
Ln agricultural labor used (Person-days/ha)			-0.34* (0.15)			0.05 (0.09)			-0.20 (0.18)
Unique crop produced (#)			-0.05 (0.04)			0.12*** (0.03)			-0.17** (0.05)
Unique livestock types owned (#)			-0.01 (0.05)			0.05 (0.04)			-0.07 (0.05)
Ln total precipitation (mm)			1.57* (0.50)			0.67*** (0.16)			1.27* (0.54)
Rainfall variability			-0.84* (0.44)			-1.32*** (0.28)			-0.22 (0.35)
Travel time to the closest weekly market (hr)			-0.06 (0.18)			0.35** (0.14)			-0.38** (0.15)
Number of observations					394				
R2	0.090	0.288	0.395	0.012	0.154	0.400	0.146	0.314	0.434

Note: Reported are OLS coefficient estimates and robust standard errors (in parentheses). HDDS stands for household dietary diversity score. Low women's empowerment group is the omitted category.

Table 2.A5: Associations between women's empowerment and household food security (Table 2.A4 cont'd)

	Food secure			Worried about food shortage (past week)		
	29.10***	24.38***	30.28***	-38.40***	-31.49***	-24.63***
High women empowerment	(6.10)	(6.21)	(6.64)	(5.86)	(3.63)	(5.22)
Moderate women empowerment	8.59	12.21	25.73*	-29.98**	-26.11**	-15.04*
	(11.38)	(10.98)	(11.23)	(9.73)	(7.72)	(6.58)
Household head age (years)		-0.04	-0.17		-0.07	-0.16
		(0.23)	(0.16)		(0.19)	(0.21)
Female head/spouse education (years)		0.23	0.36		0.82	0.42
		(1.27)	(1.30)		(0.92)	(0.98)
Male head/spouse education (years)		0.23	0.06		0.52	0.53
		(0.75)	(0.80)		(1.41)	(1.41)
Dependency ratio		-1.53	-3.26		4.67	4.24
		(4.03)	(4.25)		(3.08)	(3.31)
Operated land (ha)		1.31	1.50		0.65	-0.63
		(1.10)	(2.23)		(0.58)	(1.05)
Durable agr. assets (except land) (index)		-2.30	2.44		-8.02***	-3.54
		(2.70)	(4.09)		(1.96)	(2.39)
Durable non-agr. assets (index)		8.74	6.32		-5.28**	-7.44**
		(4.74)	(5.69)		(1.58)	(2.38)
Ln fertilizers used (ka/ha)			1.01			-1.51
			(1.75)			(1.43)
Ln manure used (kg/ha)			-0.53			0.10
			(1.10)			(0.72)
Ln improved seeds purchased (Birr/ha)			-0.42			0.38
			(0.86)			(0.81)
Ln cost of hired labor (Birr/ha)			1.38			-0.31
			(0.88)			(0.91)
Ln agricultural labor used (Person-days/ha)			5.07			-0.29
			(6.86)			(4.42)
Unique crop produced (#)			-2.82			-0.22
			(2.02)			(0.97)
Unique livestock types owned (#)			-5.28			-1.98
			(4.21)			(2.25)
Ln total precipitation (mm)			22.28			6.53
			(14.88)			(8.36)
Rainfall variability			-37.38***			-30.03***
			(9.75)			(7.54)
Travel time to the closest weekly market (hr)			8.36			4.34
			(4.42)			(3.75)
Number of observations				394		
R2	0.064	0.099	0.150	0.150	0.238	0.265

Note: Reported are OLS coefficient estimates and robust standard errors (in parentheses).

Low women's empowerment group is the omitted category.

Table 2.A6: Associations between women's empowerment and household food security (Table 2.A4 cont'd)

	Months of food shortage (past year)			Months of food shortage (lean season)		
High women empowerment	-1.14** (0.34)	-0.69* (0.30)	-0.61 (0.38)	-0.64*** (0.15)	-0.40** (0.12)	-0.44** (0.14)
Moderate women empowerment	-0.80* (0.39)	-0.58* (0.27)	-0.15 (0.25)	-0.29 (0.22)	-0.21 (0.15)	-0.11 (0.16)
Household head age (years)		0.01 (0.01)	0.00 (0.01)		0.00 (0.00)	0.00 (0.00)
Female head/spouse education (years)		0.05 (0.04)	0.05 (0.04)		0.01 (0.02)	0.01 (0.02)
Male head/spouse education (years)		0.03 (0.03)	0.02 (0.04)		0.04** (0.02)	0.03* (0.02)
Dependency ratio		0.03 (0.13)	0.01 (0.13)		0.12 (0.10)	0.12 (0.10)
Operated land (ha)		-0.01 (0.02)	-0.06 (0.05)		-0.01 (0.01)	-0.02 (0.02)
Durable agr. assets (except land) (index)		-0.36** (0.12)	-0.22 (0.13)		-0.15* (0.07)	-0.09 (0.07)
Durable non-agr. assets (index)		-0.26** (0.08)	-0.31** (0.11)		-0.18*** (0.05)	-0.19** (0.07)
Ln fertilizers used (ka/ha)			-0.03 (0.11)			0.02 (0.06)
Ln manure used (kg/ha)			0.01 (0.02)			-0.00 (0.02)
Ln improved seeds purchased (Birr/ha)			0.02 (0.04)			0.02 (0.03)
Ln cost of hired labor (Birr/ha)			-0.01 (0.02)			-0.00 (0.02)
Ln agricultural labor used (Person-days/ha)			-0.07 (0.27)			0.00 (0.18)
Unique crop produced (#)			-0.04 (0.05)			-0.02 (0.03)
Unique livestock types owned (#)			-0.13* (0.06)			-0.09** (0.03)
Ln total precipitation (mm)			0.62* (0.30)			0.17 (0.14)
Rainfall variability			-0.72* (0.30)			-0.07 (0.18)
Travel time to the closest weekly market (hr)			0.02 (0.13)			-0.06 (0.07)
Number of observations	394					
R2	0.088	0.202	0.235	0.072	0.182	0.200

Note: Reported are OLS coefficient estimates and robust standard errors (in parentheses).

Low women's empowerment group is the omitted category.

Table 2.A7: Pairwise correlations of PCA components on Food Security and Food Security variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Global Food Security Index - Component 1	1.000									
(2) Global Food Security Index - Component 2	0.000	1.000								
(3) Global Food Security Index - Component 3	0.000	0.000	1.000							
(4) HDDS - all foods	0.766	0.553	-0.140	1.000						
(5) HDDS - own produced	0.426	0.330	0.773	0.461	1.000					
(6) HDDS - purchased	0.667	0.467	-0.555	0.837	0.039	1.000				
(7) Food secure	0.568	0.332	0.253	0.415	0.325	0.344	1.000			
(8) Worried about food shortage (past week)	-0.552	0.433	0.099	-0.182	-0.059	-0.184	-0.180	1.000		
(9) Months of food shortage (past year)	-0.742	0.561	-0.035	-0.266	-0.157	-0.229	-0.201	0.476	1.000	
(10) Months of food shortage (lean season)	-0.715	0.573	-0.046	-0.237	-0.137	-0.200	-0.204	0.431	0.854	1.000

Note: Columns represent survey questions shown in the corresponding row number.

B Figures

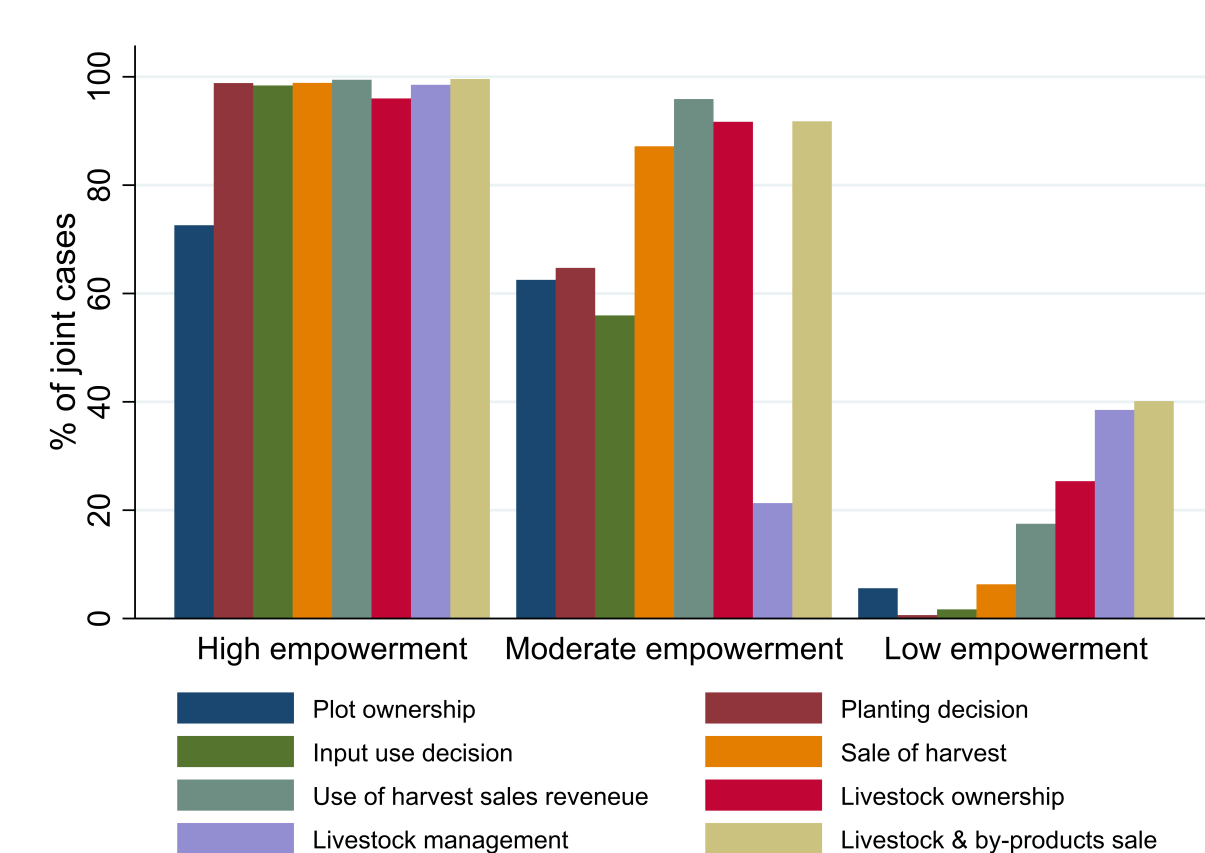


Figure 2.B1: Descriptive summary of joint ownership by empowerment-based farm types and empowerment domain

Note. HWE : High empowerment, MWE : Moderate empowerment and, LWE : Low empowerment

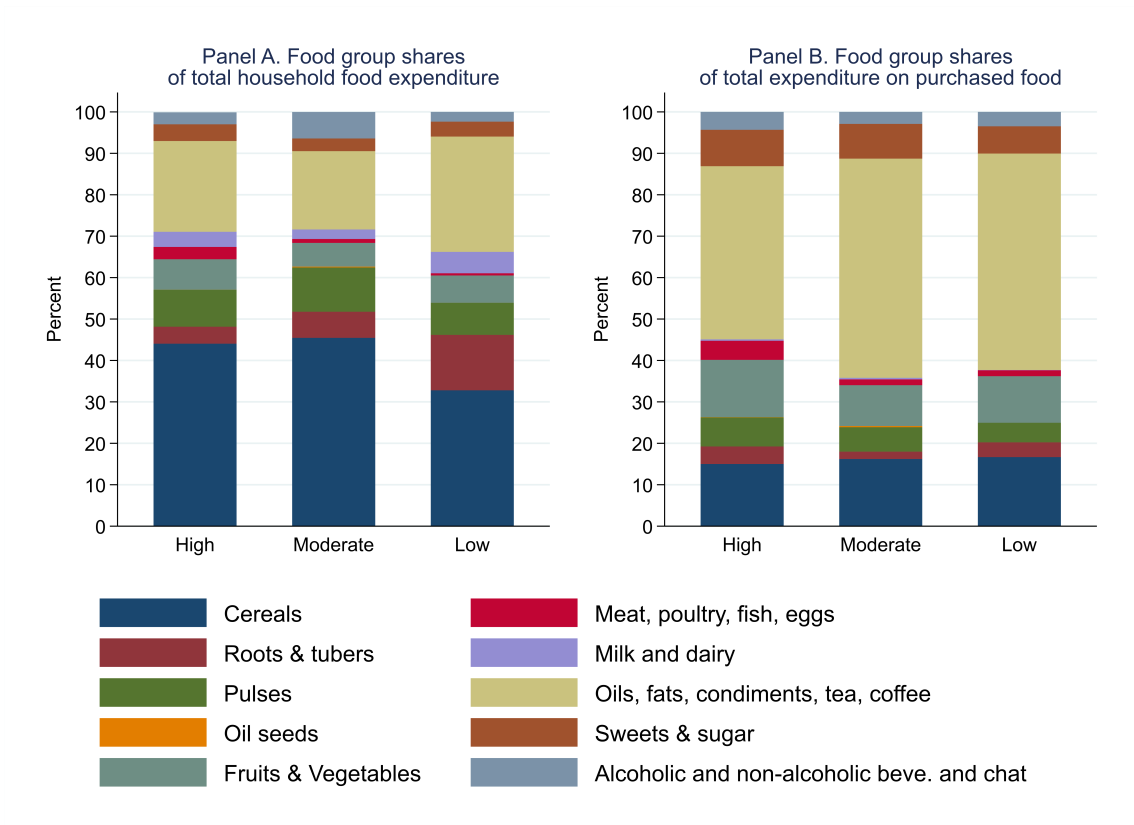


Figure 2.B2: Expenditure shares by food group and women’s empowerment domain

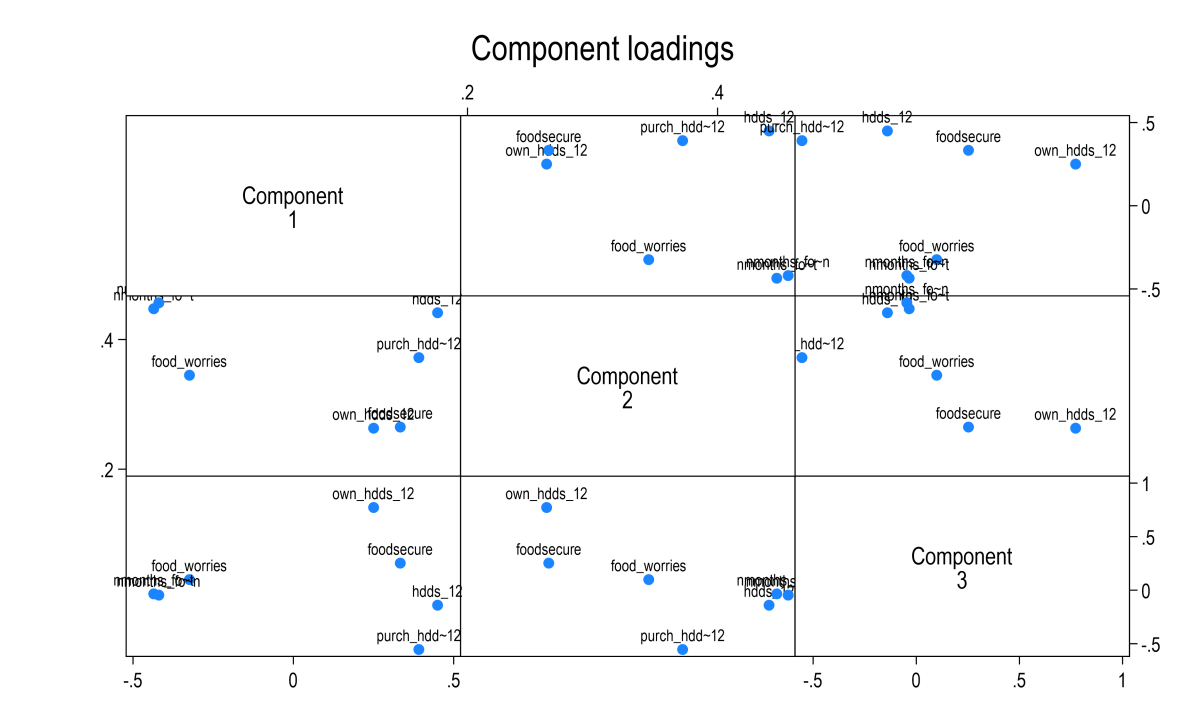


Figure 2.B3: Loading of Food Security Component

3

Determinants and Forecasts of Economic Perceptions in Sub-Saharan Africa: A Macro and Microeconomic Approach¹

Abstract: This chapter is focused on the determinants and the forecasting future economic perceptions in sub-Saharan Africa by accounting for both macroeconomic and microeconomic factors. The analysis covers 36 countries in sub-Saharan Africa from 2011 to 2018. We combine microeconomic data from three different rounds of Afrobarometer surveys with several macroeconomic data sets from several sources. The analysis shows a paradox that the majority of Africans claim to have lived in very poor past and present economic conditions, but believe the future will be much better. To determine the factors explaining their optimism for the future, we use hierarchical regression method. The results show that their optimism depends on past and current economic conditions, the actions of the institutions that govern the country, macroeconomic stability and the degree of fragmentation in the country. In order to predict the type of future economic conditions, we use the regression tree method. Individuals are more optimistic in the presence of good past and present economic conditions, low levels of ethnolinguistic and religious fragmentation, a decent level of political stability, the absence of violence and with the policies of the President of the Republic. The individuals become pessimistic, or neutral if these factors are moderate or low.

Keywords: Economic conditions, Multilevel Method, Regression trees, Afro-barometer

JEL Codes: O11, O12, C33, C39

¹This chapter is co-written with Hervé AKINOCHO (Director of Center for Research and Opinion Polls (CROP)/Afrobarometer), and under revision at *Journal of International Development*.

3.1 Introduction

Predicting or forecasting economic prospects remains a challenging task, despite significant improvements in forecasting models over the years. Today, numerous studies across various fields are dedicated to forecasting future economic conditions, a task crucial for researchers and economic policymakers alike. For instance, major institutions like the Organisation for Economic Co-operation and Development (OECD) publish annual reports based on econometric models to assess economic prospects within their member countries². The OECD notably produces two reports per year (i.e. Economic Outlook), to anticipate economic conditions in member countries (OECD, 2024). Other international institutions, such as the United Nations (UN) (United Nations Department of Economic and Social Affairs, 2024), the International Monetary Fund (IMF) (International Monetary Fund. Research Dept., 2023), and the World Bank (World Bank, 2024b), also rely on a series of studies and models to evaluate global and regional economic outlooks (Turner, 2016; Altshuler et al., 2016)).

These forecasts are typically constructed from macroeconomic data and aim to project short- and medium-term trends, while also simulating various realistic scenarios. Each institution employs its own forecasting methods, which have evolved over time to reduce estimation biases and improve predictive accuracy. For example, the OECD currently uses the global NIGEM (National Institute Global Econometric Model), while the IMF relies on the Global Projection Model (GPM), a general equilibrium model that incorporates multiple countries or regions (Jakab et al., 2015; Carabenciov et al., 2013). These models are often derived from Dynamic Stochastic General Equilibrium (DSGE) models, which are widely used by central banks for their forward-looking economic studies (Tovar, 2009).

An interesting observation from these analyses is that most forecasting models rely almost exclusively on macroeconomic data. Few explicitly incorporate microeconomic dimensions, although these are sometimes reflected in the assumptions made by the models. Surveys focusing on individuals, such as Afrobarometer, provide data on past, present, and future perceptions of economic conditions, and such data could enrich macroeconomic forecasting models.

²See OECD Economic Policy Papers (<https://doi.org/10.1787/2226583X>)

Current and future economic conditions in developing countries, particularly in Africa, remain a central topic in economic literature. In 2024, the African Development Bank (AfDB) published its African Economic Outlook report titled *Driving Africa's Transformation: The Reform of the Global Financial Architecture* ([African Development Bank Group, 2024](#)). This report highlights improving economic performance in several regions of the continent, with an average growth rate projected at 4% for the upcoming year. African economic prospects are primarily driven by the recovery of Foreign Direct Investment (FDI), structural reforms, and the adoption of digital technologies in key sectors such as agriculture and infrastructure.

However, despite these positive prospects, the report underscores persistent challenges, including regional disparities and macroeconomic instability in some economies. These projections are based primarily on macroeconomic variables such as GDP growth, inflation, and public investment. However, little effort is made to incorporate microeconomic variables into growth and development models. This limits the understanding of smaller-scale effects, particularly in terms of household welfare, social inequalities, and the impact of economic policies on vulnerable populations.

Studying public opinions on future economic conditions is of strategic importance in economics, as these perceptions directly influence the behaviors and decisions of economic agents. When individuals express optimism or pessimism about future economic conditions, they shape not only their own choices regarding consumption, savings, and investment but also indirectly impact the overall economic climate through a contagion effect. This “agent confidence” is thus a foundational element of economic stability, acting as a feedback mechanism that can either accelerate or hinder growth.

In sub-Saharan Africa particularly, where economic conditions are often marked by heightened volatility and limited institutional resilience, understanding the underlying drivers of economic opinions becomes crucial. By analyzing these perceptions, this study aims to shed light on the complex relationships between past economic experiences, current conditions, and future expectations to identify leverage points that could strengthen agent confidence. In essence, this research contributes to a deeper understanding of development dynamics in Africa and offers insights

for policies that aim to stabilize expectations and, consequently, enhance regional economic resilience.

In this study, we focus on analyzing and forecasting opinion on future economic conditions in Sub-Saharan Africa, combining both macroeconomic and microeconomic dimensions over the period 2011-2018. We focus on this region due to the availability of high-quality data at both levels. The microdata comes from three cycles of Afrobarometer surveys, which not only gauge citizens' opinions on past, present, and future economic conditions but also collect information on governance, corruption, and democracy in their countries. To analyze the main determinants of citizens' opinions on future economic conditions, we use the multilevel (or mixed) regression method, which accounts for both direct effects of variables and contextual effects that can influence inference due to the structure of the data. To predict these opinions, we use the regression tree method, a machine learning technique that allows the integration of a large number of variables and the identification of the most discriminating combinations for predicting future economic conditions.

The remainder of this chapter is structured as follows. Section 3.2 presents the stylized fact. Section 3.3 describes the data and the methodology. The results are discussed in Section 3.4. Section 3.5 presents the results of prediction, and Section 3.6 concludes.

3.2 Stylized fact

In this section, we present some stylized facts about optimism and the evolution of sub-Saharan Africans' opinions on future economic conditions.

3.2.1 The paradox of african optimism

La Figure 3.1 illustrates public opinions in several African countries regarding past, present, and future economic conditions.³

Firstly, concerning past economic conditions (Q6), approximately 68% of respondents believe the situation has worsened or remained unchanged over the past year. Only 32% view the past situation positively, with 4% describing it as “much bet-

³Calculations are based on microeconomic survey data covering 36 sub-Saharan countries from 2011 to 2018 (see the section on data for more details). We analyze the perceptions of sub-Saharan Africans regarding their past, present, and future economic conditions. Refer to Section 3.3 on data and the Appendix A for more details on the survey questions and response options.

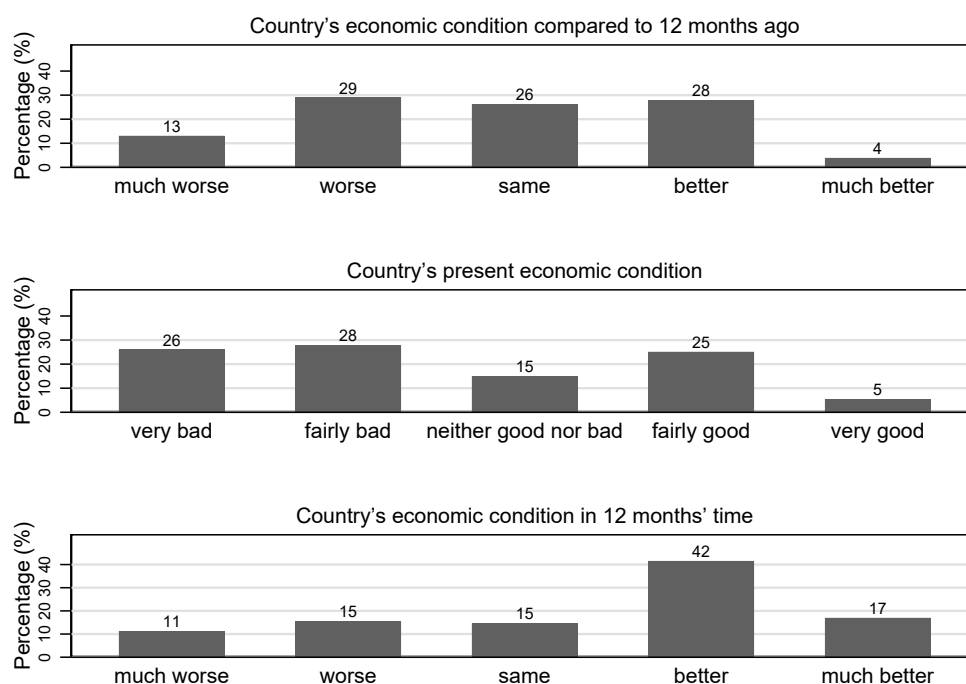


Figure 3.1: Analysis of opinions on past, present and future economic conditions in countries

ter”. These results reveal a general perception of economic stagnation or regression, indicating a predominantly negative view of past economic conditions.

Opinions on current economic conditions (Q4a) also reflect a largely negative sentiment: 70% of respondents describe the situation as “very bad”, “fairly bad”, or “neither good nor bad”. Only 30% have a favorable perception of present conditions, suggesting that most people perceive the current economic context as unfavorable.

However, regarding future economic prospects (Q7), respondents show some optimism: 59% foresee an improvement in economic conditions in the coming year (with 42% expecting conditions to be “better” and 17% “much better”). In contrast, 41% remain cautious, anticipating stable or even deteriorating conditions.

We repeat the same analyses of past, present, and future economic conditions for each of the three survey rounds used. The analysis is presented in Figures 3.B1, 3.B2, and 3.B3 in the Appendix. Similar results emerge, indicating that, overall, although Africans report living in countries with very difficult or relatively unchanged past and present economic conditions, they remain optimistic about the future.

These findings illustrate a “paradox of optimism”, where, despite difficult past

and present economic experiences, a majority remains hopeful for a better future for their country.

3.2.2 Evolution of the opinion on future economic conditions

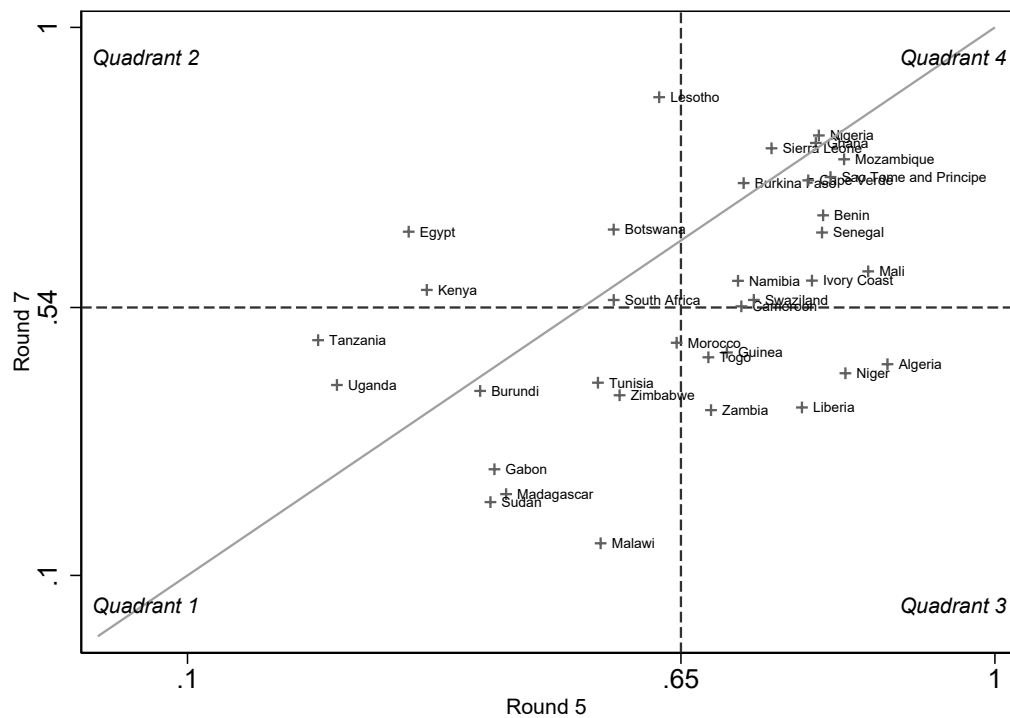


Figure 3.2: Evolution of the rate of people claiming a better economic future

We're now focusing on the dynamics of this optimism over time. The analysis of Figure 3.2 reveals a division of Sub-Saharan African countries into four quadrants, based on the evolution of optimism regarding future economic conditions between Rounds 5 (2011-2013) and 7 (2016-2018) of the Afrobarometer surveys (see Section 3.3 on data).

Overall, there is a noticeable decrease in optimism, dropping from 65% in Round 5 to 54% in Round 7, indicating an 11% decline. This suggests a growing pessimism among Africans about their country's economic outlook, potentially reflecting a deteriorating economic perception over this period. However, the evolution remains highly heterogeneous across countries, and the quadrant analysis provides a more detailed view of this trend.

Quadrant 1 includes countries where optimism rates remained below average

in both rounds, indicating sustained economic pessimism; Sudan, often marked by political instability, exemplifies this category. *Quadrant 2* includes countries where optimism rates were below average in Round 5 but rose above average by Round 7, reflecting increased confidence in future economic conditions. This group includes countries like Egypt, Kenya, Lesotho, and Botswana, where the proportion of optimistic individuals rose compared to the sample average. Conversely, *Quadrant 3* contains countries where optimism rates were initially above average in Round 5 but fell below average in Round 7, showing a shift towards marked pessimism. Examples include Togo, Niger, Algeria, Guinea, and Liberia. Finally, *Quadrant 4* encompasses countries that maintained high optimism rates above the SSA average in both rounds, indicating sustained confidence in future economic prospects. Countries such as Benin, Mali, Senegal, Côte d'Ivoire, and Namibia fall into this category.

The first bisector (line of equation $y = x$) allows us to compare changes in optimism for each country. Countries above this line, like Lesotho and Egypt, show significant increases in optimism rates regarding the future economic perspectives, while those below it, such as Liberia, Malawi, and Algeria, exhibit notable declines. These results highlight the heterogeneous evolution across countries and the diverse economic and social factors shaping future economic perceptions across Sub-Saharan African nations.

3.3 Data and methodology

In this section, we first discuss the data sources used, then the methodology, and finally the variables.

3.3.1 Data

The dataset used in this study covers 36 sub-Saharan African countries over the period from 2011 to 2018 (see Table 3.A1 in Section A of the appendix), and is drawn from several databases (refer to Tables 3.A3 and 3.A4 for variable definitions and sources). The sample comprises 112,832 observations. The individual-level (microeconomic) data come from the last three Afrobarometer survey rounds, specifically rounds 5, 6, and 7, conducted over the periods 2011–2013, 2014–2015, and 2016–2018, respectively, across approximately 30 African countries. These rounds

significantly expanded the coverage compared to the earlier Afrobarometer rounds, which surveyed fewer countries.⁴ The Afrobarometer surveys aim to capture African citizens' opinions on governance, democracy, corruption, economic conditions, and other key national issues. As noted by [Buzasi \(2015\)](#), these data are frequently employed to study of political, developmental, and historical discussions.

The consistency in the survey questions across different rounds allows for cross-round comparison and enables the combination of data from the last three rounds so that variables remain unchanged. Macroeconomic data are drawn from multiple sources, including the World Bank's Worldwide Governance Indicators (WGI), the Polity IV Project, the United Nations Development Programme's Human Development Data, the Armed Conflict Dataset from the Uppsala Conflict Data Program (UCDP) and the Peace Research Institute Oslo (PRIO), and finally, data from the International Monetary Fund (IMF), supplemented by information from other reliable online sources.

After data processing, we end up with a size of 111924 individuals covering all 36 countries.

3.3.2 Methodology

To study the determinant of the opinion on the future economic conditions, we use the multilevel, or mixed, or hierarchical regression method unlike simple regression methods with binary dependent variable. This new method admits a certain number of theoretical and statistical advantages ([Givord et al., 2016](#); [Buxton, 2008](#); [Bressoux, 2007](#); [Diez-Roux, 2000](#); [Osborne, 2000](#)). Indeed, when data are structured at several levels or when individuals share a common environment (e.g. same countries for citizens, same class for students), it plays an important role and can affect their studied behaviour. This is called "context effects" or "environmental effects". In the presence of these effects, the hypotheses of homoscedasticity and independence of errors of the Least Ordinary Square (OLS) are challenged; and estimation using OLS biases the results (see [Givord et al. \(2016\)](#); [Bressoux \(2007\)](#) for more information). The multilevel method has gained popularity in social science

⁴While the earlier rounds covered fewer than 20 countries, round 5 includes 35 countries, round 6 covers 36 countries, and round 7 surveys 34 countries. This study utilizes a sample of 36 countries; Burundi is excluded due to missing surveys in rounds 6 and 7, while Gambia and São Tomé and Príncipe were added in round 7.

studies that focus on corruption, trust, communication, education, health, etc (Car-
iolle, 2018; Buzasi, 2015; Vanderlinde et al., 2014; Lavallée et al., 2008; Subramanian
et al., 2003; Yuan and Keeves, 2001; Rosenbaum and Hanson, 1998). We summarize
in a few words the advantage of using the hierarchical modeling technique as follows:
according to Osborne (2000), this technique allows not only to take into account the
direct effects of variables, but also the contextual effects while correcting problems
of statistical inference⁵ due to the grouping of individuals. In addition to interest
in group effects, it directly combines fixed and random effects to distinguish and
estimate effects due to observed and unobserved group characteristics. In addition,
this method facilitates the inference of results because the groups in the sample are
treated as randomly drawn from a population of groups.

Given the multilevel methodology, our general specification is as follows:

$$Y_{iyc} = \beta_0 + X_{iyc}\beta_1 + X_{yc}\beta_2 + X_c\beta_3 + \alpha_c + \alpha_{yc} + \epsilon_{iyc} \quad (3.1)$$

The subscript i refers to level-1 observations, representing individuals; y to level-
2 observations, specifically years; and c to level-3 observations, namely countries.
However, given that the data structure is not a panel but rather repeated cross-
sectional surveys with different individuals and countries over time, we adopt the
following specification:

$$Y_{ik} = \beta_0 + X_{ik}\beta_1 + X_k\beta_2 + \alpha_k + \epsilon_{ik} \quad (3.2)$$

In this case, i denotes level-1 observations (individuals), and k represents level-2
observations, specifically country-years, grouping individuals by country-year com-
binations.

Here, Y represents our dependent variable (a binary variable, see subsection 3.3.3
for variable definitions) that captures opinions on economic conditions. X_{ik} includes
individual-level variables (microeconomic variables), and X_k includes country-year
level variables (macroeconomic variables that vary by country and year). The term
 α_k accounts for specific effects at each level k , while ϵ represents the error term,

⁵The inference concerns the significance of the coefficients. If the hierarchical data structure is
not taken into account, the estimate may lead to an overestimation of statistical significance. See
Osborne (2000); Diez-Roux (2000); Tom et al. (1999); Hox (1995).

Table 3.1: Descriptive statistics of the variables

VARIABLES	N	Mean	Standart Deviation	Minimun	Maximum
Urban (=1)	111,924	0.438	0.496	0	1
Age	111,924	36.58	14.27	18	106
Present living conditions	111,924	2.734	1.205	1	5
Past country's conditions	111,924	2.805	1.101	1	5
Political interest	111,924	0.907	0.710	0	2
Satisfaction with democracy	111,924	2.410	1.036	0	4
Education	111,924	3.542	2.185	0	9
Gender	111,924	0.479	0.500	0	1
Lived Poverty Index	111,924	1.184	0.922	0	4
Year				2011	2018
Level of democracy	111,924	4.139	4.466	-9	10
Human Development Index	111,924	0.537	0.0956	0.340	0.749
Conflit and violence (Last year)	111,924	0.0395	0.195	0	1
Government debt	111,924	44.34	22.49	7.601	125.8
Inflation	111,924	7.086	7.987	-1.090	63.30
Trust in institution	111,924	1.415	0.750	0	3
Government performance	111,924	1.880	0.775	1	4
Government satisfaction	111,924	2.532	0.805	1	4
Political Participation	111,924	1.995	1.211	0	4
Media exposure	111,924	1.322	1.243	0	4
Institutional quality	111,924	-0.519	0.550	-1.667	0.887
Future economic condition (Better = 1)	111,924	0.586	0.493	0	1

assumed to be independently and identically distributed.

Our baseline models are estimated using a multilevel mixed-effects logistic regression. As a robustness check, we also employ multilevel mixed-effects probit regressions. Additionally, we include simple logit and probit regressions in each analysis to ensure robustness across different specifications.

3.3.3 Variables

In this subsection, we detail the dependent variable concerning public opinions on future economic conditions and the range of control variables considered. A comprehensive overview of these control variables is provided in Appendix A Tables 3.A3 and 3.A4.

Dependent Variable

To assess the perception of future economic orientation of a country, we use question 7 from the Round 7 Afrobarometer survey (Q7: Looking to the future, would you say that the economic conditions of this country will be better or worse in a 12-month period?). Respondents can select from five response options: 1 (Much

worse), 2 (Worse), 3 (Same), 4 (Better), and 5 (Much better), with two additional categories, 8 (Refused) and 9 (Don't know). For this analysis, we limit the responses to the five main modalities, coding the variable as binary. Responses of 4 or 5 are coded as 1, indicating optimism, while responses of 1, 2, or 3 are coded as 0, indicating a lack of optimism. This coding approach, similar to that used by [Buzasi \(2015\)](#) in an Afrobarometer survey study, reclassifies respondents' levels of confidence to facilitate analysis.

Explanatory Variables

To capture the factors influencing respondents' views on future economic conditions, we incorporate both micro- and macroeconomic factors, capturing current and past conditions, and, governance and institutions quality.

At the microeconomic level, socio-demographic variables such as residential area (urban or rural), age (Q1), gender (Q101, recoded in 1 for female and 0 for male), and educational level (Q97) provide insight into individual characteristics. These variables are taken from Afrobarometer survey data. Literature suggests that differences in quality of life and inequalities between urban and rural areas affect satisfaction levels, potentially influencing optimism about economic conditions ([Sørensen, 2014](#); [Shucksmith et al., 2009](#)). Similarly, variations in life satisfaction based on gender, education, and age have been widely documented ([Joshanloo, 2018](#); [Oshio, 2012](#); [Gaymu and Springer, 2010](#)). These socio-demographic variables enable us to capture differences in individuals' outlooks based on their backgrounds.

To account for past and present economic perceptions, we use questions Q6 (Looking back, how do you rate economic conditions in this country compared to twelve months ago?) and Q4a (In general, how would you describe: The present economic condition of this country?). These perceptions are critical as they often inform views on future economic trends. Since many forecasting models rely on past data, they provide essential context for understanding individuals' economic expectations.

Institutional Variables

We integrate several variables to account for political and institutional influences, as these significantly impact economic perceptions. Based on [Hutchison and Johnson \(2017\)](#); [Hutchison \(2011\)](#); [Hutchison and Johnson \(2011\)](#), the institutional

variables include *Government Performance*, *Satisfaction with Democratic*, *Government Satisfaction*, *Political Participation*, *Political Interest*, *Media Exposure*, and *Trust in Institutions*. These composite indices are constructed using Cronbach's Alpha method (Cronbach and Meehl, 1955), generally yielding an alpha between 70% and 90% for validity and reliability (DeVellis, 2016; Bland and Altman, 1997; Peterson, 1995). The *Government Performance* index, slightly under 70% reliability at 69.79%, measures opinions on job creation (Q56c) and price stability (Q56d) (see Figure 3.B4 in the appendix, which shows the values of Cronbach's alpha coefficient within the required range, and Table 3.A3 in Appendix A for the related questions used).

Other institutional variables, such as *Media Exposure* and *Trust in Institutions*, are derived by aggregating responses across related questions. The Afrobarometer Lived Poverty Index, which ranges from 0 (no poverty) to 4 (extreme poverty), assesses respondents' frequency of experiencing shortages in basic needs like food, water, and medical care (Mattes et al., 2016; Dulani et al., 2013; Noble and Wright, 2013; Mattes, 2008).

Macroeconomic Variables

We further control for country-specific factors by incorporating macroeconomic variables, reflecting both economic and political contexts. The *Human Development Index* measures development across health, education, and living standards. *Inflation* rates capture variations in living costs. *Governance quality*, *Level of democracy*, and conflict prevalence (*Conflict and Violence - Last year*) provide insights into each country's institutional environment, particularly stability and law enforcement. For example, the Conflict and Violence variable is coded as 1 if a conflict has resulted in over 25 deaths, affecting individuals' economic outlook. This criterion identified Sudan and Nigeria as cases of heightened instability due to internal conflicts. *Government debt* levels, reflecting economic policy directions, also influence perceptions, with some agents adopting a Ricardian view that future taxes will offset current debt (Mosley and Rosendorff, 2023).

In the appendix A, Tables 3.A3 and 3.A4 for micro and macroeconomics variables respectively, provides detailed definitions and sources for each variable, with descriptive statistics in Table 3.A1. This comprehensive approach minimizes multi-

collinearity risks and ensures robust results across our multilevel regression models.

3.4 Results and discussion

To estimate the factors that determine perceptions of future economic conditions, we use a logit model with two approaches. The first approach, serving as our baseline, applies the multilevel regression method (regressions 1, 2, 3, and 4), while the second approach, a robustness check, uses a simple logit model with fixed effects (regressions 5, 6, and 7). This setup results in seven different regressions. Regression (1) includes no variables but provides information on interclass variance (ICC). Regressions (2) and (5) introduce socio-demographic variables; regressions (3) and (6) add institutional variables; and regressions (4) and (7) further incorporate macroeconomic variables. Our multilevel model is estimated at two levels: individual-level data at the first level and country-year data at the second level, enabling us to account for survey repetition in a given country over time.

Since the baseline model is nested within the others, we perform a likelihood-ratio (LR) test, applying it to models with added institutional and macroeconomic variables compared to the baseline model that includes only socio-demographic variables. This test assesses whether the additional variables provide significant new information relative to the baseline specification. To evaluate model accuracy, we report the percentage correctly classified, sensitivity, and specificity of each model. Sensitivity reflects the probability that an individual perceives favorable future economic conditions when the model predicts such an outlook, while specificity indicates the probability of perceiving unfavorable conditions when the model predicts a poor economic outlook for the country. We use as a benchmark the sample proportion (59%) of respondents who indicate that future economic conditions will be better

Table 3.2 presents the results of the various estimations. We reported odds ratio in this table. The hierarchical, or multilevel, approach applies two levels for estimation: the individual level (level 1), comprising 111,924 individuals, and the group level (level 2), consisting of 107 country-year groups. The intraclass correlation coefficient (ICC) and level 2 variance in regression (1) reveal that while groups are relatively distinct, individuals within the same group exhibit significant similarity. The likelihood ratio test confirms that adding additional variables provides valuable

Table 3.2: Result with logit method regression

Dependent variable : Future country's economic condition							
	Multilevel Method				Logit simple		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban (=1)		0.911*** (0.024)	0.993 (0.025)	0.992 (0.025)	0.910*** (0.024)	0.992 (0.025)	0.992 (0.025)
Age		0.995*** (0.001)	0.994*** (0.001)	0.994*** (0.001)	0.995*** (0.001)	0.994*** (0.001)	0.994*** (0.001)
Gender		1.022 (0.021)	1.012 (0.020)	1.013 (0.020)	1.023 (0.021)	1.013 (0.020)	1.013 (0.020)
Education		0.987 (0.008)	0.978*** (0.008)	0.978*** (0.008)	0.987 (0.008)	0.978*** (0.008)	0.978*** (0.008)
Past country's conditions			1.507*** (0.047)	1.507*** (0.047)		1.506*** (0.047)	1.506*** (0.047)
Present living conditions			1.250*** (0.019)	1.250*** (0.019)		1.250*** (0.019)	1.250*** (0.019)
Government performance			1.207*** (0.028)	1.207*** (0.028)		1.206*** (0.028)	1.206*** (0.028)
Political participation			1.042*** (0.013)	1.042*** (0.013)		1.043*** (0.013)	1.043*** (0.013)
Political interest			0.990 (0.016)	0.990 (0.016)		0.989 (0.016)	0.989 (0.016)
Media exposure			0.965** (0.014)	0.965** (0.014)		0.964** (0.014)	0.964** (0.014)
Lived Poverty Index			0.870*** (0.016)	0.870*** (0.016)		0.870*** (0.016)	0.870*** (0.016)
Satisfaction with democracy			1.206*** (0.018)	1.206*** (0.018)		1.207*** (0.018)	1.207*** (0.018)
Government satisfaction			1.327*** (0.028)	1.327*** (0.028)		1.327*** (0.028)	1.327*** (0.028)
Trust in institution			1.184*** (0.028)	1.183*** (0.028)		1.184*** (0.028)	1.184*** (0.028)
Human Development Index				0.184** (0.153)			0.000*** (0.000)
Institutional quality				1.142 (0.210)			1,402.934*** (90.595)
Level of democracy				1.011 (0.017)			0.539*** (0.003)
Conflit and violence (Last year)				3.083*** (1.011)			12.702*** (1.236)
Government debt				1.001 (0.003)			1.030*** (0.000)
Inflation				0.968*** (0.011)			0.817*** (0.003)
Constant	1.472*** (0.125)	1.935*** (0.200)	0.073*** (0.012)	0.214*** (0.115)	0.939 (0.046)	0.032*** (0.004)	2.958e+17*** (1.293e+17)
Observations	111,924	111,924	111,924	111,924	111,903	111,903	111,903
Number of groups	107	107	107	107			
LR Test			14362***	14381***		14332***	14332***
AIC	135904	135727	121386	121378	135090	120778	120778
BIC	135923	135785	121540	121590	135129	120913	120913
Percent correctly classified					66.12	72.13	72.13
Sensitivity					66.06	72.72	72.72
Specificity					66.21	71.29	71.29
R2 Mcfadden					0.11	0.2	0.2
Pseudo R2					0.13	0.22	0.22
ICC	0.19	0.19	0.16	0.14			
Variance level : Country-year	0.75	0.75	0.63	0.53			

Robust standart error in parentheses. *** p<0.01, ** p<0.05, * p<0.1

information. When comparing models based on the AIC and BIC information criteria, it is challenging to differentiate between models that include only institutional variables (models 3 and 6) and those that also incorporate macroeconomic variables (models 4 and 7). Due to its theoretical advantages in regression contexts, we prioritize the AIC criterion over the BIC (Yang, 2005). Furthermore, the BIC relies on assumptions that are theoretically contentious (Burnham and Anderson, 2004; Burnham, 2002). Accordingly, the AIC criterion leads us to select models (4) and (7).

Regarding socio-demographic characteristics, the results indicate that place of residence (urban or rural) and gender do not significantly impact individuals' perceptions of the country's future economic conditions. In other words, there are no notable differences based on either location or gender. However, holding all other variables constant, an increase of one unit in age decreases the likelihood that an individual will view the country's future economic conditions positively, with a factor of 0.995. This finding suggests that as Africans age, they tend to view future economic conditions more pessimistically.⁶ Furthermore, higher levels of education are associated with a greater likelihood of viewing the country's future economic conditions negatively.

The analysis also suggests that individuals' experiences of past and present economic conditions strongly influence their outlook on the country's economic future. Individuals who have experienced favorable past economic conditions are more likely to anticipate positive future economic conditions for their country. This pattern is similarly observed with current living conditions; individuals enjoying favorable present conditions are more likely to predict a positive economic future for their country.

Some institutional factors play significant roles in shaping individuals' opinions about future economic conditions. Factors such as government performance, political participation, satisfaction with democracy, approval of government policies, and trust in institutions increase the likelihood that people view future economic

⁶Several studies have shown a U-shaped relationship between age and life satisfaction Frijters and Beaton (2012); De Ree and Alessie (2011); Frijters et al. (2004). To test this, we introduced the squared age variable in our regressions and found a similar U-shaped relationship. This suggests that while older individuals are more likely to view the economic future pessimistically, beyond a certain age, individuals tend to become more optimistic again.

prospects positively. For instance, individuals who are highly satisfied with government performance are more likely to believe that the country's future conditions will improve. When governments make substantial efforts in areas like price stabilization and job creation, citizens tend to be optimistic about the nation's economic future. Similarly, individuals who participate in political events, such as community meetings and political discussions, are more likely to have positive views about the country's future. Furthermore, a satisfactory level of democracy, as perceived by citizens, enhances optimism for future conditions. Likewise, when the actions of the president, members of the national assembly, and local officials align with citizens' expectations, people are more likely to believe in a brighter future. This optimism extends to those who have a high level of trust in political institutions, including the President, National Assembly, Independent Electoral Commission, ruling party, and opposition parties.

Conversely, certain factors decrease the likelihood that subsaharian Africans will expect better future economic conditions. This is particularly true for individuals in low-income households who experience difficulties or shortages of basic necessities, such as inadequate food, insufficient drinking water, lack of financial resources, limited access to healthcare, and lack of fuel for cooking. Additionally, individuals who frequently consume news through the media may also tend to view future economic conditions pessimistically. Interestingly, having a strong personal interest in politics—reflected by frequent discussions on political issues with friends or family—does not significantly influence individuals' views on future economic prospects.

Macroeconomic conditions play a significant role in shaping individuals' views on a country's future economic prospects. Key factors include the inflation rate, representing the evolution of the cost of living, and the country's development level. Higher inflation tends to increase pessimism about future economic prospects. Moreover, a one-percentage-point increase in the development level reduces the probability of a positive future economic outlook by 0.184 percentage points. However, institutional quality, democracy, and government debt levels appear to have no significant effect on individuals' economic outlook.

As previously mentioned, there is notable heterogeneity between groups but a degree of similarity within the same group. Given this data structure, multilevel

Table 3.3: Result with probit method regression

Dependent variable : Future country's economic condition							
	Multilevel Method				Probit simple		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Urban (=1)		0.981*** (0.005)	0.998 (0.005)	0.998 (0.005)	0.978*** (0.006)	0.998 (0.006)	0.998 (0.006)
Age		0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)	0.999*** (0.000)
Gender		1.005 (0.004)	1.003 (0.004)	1.003 (0.004)	1.005 (0.005)	1.003 (0.004)	1.003 (0.004)
Education		0.997 (0.002)	0.996*** (0.002)	0.996*** (0.002)	0.997 (0.002)	0.995*** (0.002)	0.995*** (0.002)
Past country's conditions			1.089*** (0.007)	1.091*** (0.007)		1.099*** (0.008)	1.099*** (0.008)
Present living conditions			1.047*** (0.003)	1.048*** (0.003)		1.052*** (0.004)	1.052*** (0.004)
Government performance			1.040*** (0.005)	1.040*** (0.005)		1.044*** (0.005)	1.044*** (0.005)
Political participation			1.009*** (0.003)	1.009*** (0.003)		1.010*** (0.003)	1.010*** (0.003)
Political interest			0.998 (0.003)	0.998 (0.003)		0.998 (0.004)	0.998 (0.004)
Media exposure			0.993** (0.003)	0.993** (0.003)		0.992** (0.003)	0.992** (0.003)
Lived Poverty Index			0.971*** (0.004)	0.971*** (0.004)		0.968*** (0.004)	0.968*** (0.004)
Satisfaction with democracy			1.040*** (0.003)	1.040*** (0.003)		1.044*** (0.003)	1.044*** (0.003)
Government satisfaction			1.061*** (0.005)	1.062*** (0.005)		1.067*** (0.005)	1.067*** (0.005)
Trust in institution			1.036*** (0.005)	1.036*** (0.005)		1.039*** (0.006)	1.039*** (0.006)
Human Development Index				0.698** (0.123)			0.000*** (0.000)
Institutional quality				1.029 (0.040)			5.422*** (0.084)
Level of democracy				1.002 (0.004)			0.866*** (0.001)
Conflit and violence (Last year)				1.264*** (0.088)			1.816*** (0.039)
Government debt				1.000 (0.001)			1.007*** (0.000)
Inflation				0.993*** (0.002)			0.954*** (0.001)
Constant	1.791*** (0.032)						
Observations	111,924	111,924	111,924	111,924	111,903	111,903	111,903
Number of groups	107	107	107	107			
LR Test			14342***	14361***		14311***	14311***
AIC	135906	135730	121409	121401	135100	120800	120800
BIC	135925	135788	121563	121613	135177	120935	120935
Percent correctly classified					66.11	72.02	72.02
Sensitivity					65.99	72.26	72.26
Specificity					66.28	71.67	71.67
R2 Mcfadden					0.11	0.20	0.20
Pseudo R2					0.13	0.22	0.22
ICC	0.22	0.22	0.18	0.16			
Variance level : Country-year	0.28	0.28	0.22	0.19			

Robust standart error in parentheses. *** p<0.01, ** p<0.05, * p<0.1

estimation may be less efficient in capturing variability across groups (Givord et al., 2016). To address this, we supplement our analysis with a simple logit model with country-year fixed effects (regressions 5 to 7). These results are generally consistent with those from the multilevel model, with some differences in the macroeconomic variables. Since the multilevel approach provides robust standard errors and adjusts the significance of certain variables, we focus on interpreting its results. The overall classification accuracy is estimated at 72%, with 73% specificity (correctly classifying the normal weight group) and 71% sensitivity (correctly classifying the low weight group).⁷

For more robustness check, we re-estimate the regressions using the Probit model. Table 3.3 presents the marginal effects at the mean, showing results consistent with those in Table 3.2 for all different method of regressions and additional controls.

3.5 Futher extension: Predicting opinion on fuc-ture economic conditions

Thus far, our analysis has focused on identifying the variables that explain Africans' perceptions of their countries' economic futures, with the aim of pinpointing the most significant predictors. We now turn our attention to identifying the most discriminative factors—those whose combinations can effectively predict the type of economic future an individual might anticipate for their country. To accomplish this, we utilize the regression tree technique.

The regression tree method, particularly suitable for large datasets, segments the population into homogeneous groups based on a set of discriminating variables to predict a target or dependent variable. Originally developed by Breiman et al. (1984), this technique has since been enhanced through numerous studies (Karalič, 1992; Murthy, 1998; Rokach and Maimon, 2005, 2008; Rokach, 2010). Rooted in machine learning principles, the algorithm identifies potential binary split points for each predictor variable, selecting the one that yields the highest predictive “gain” for future economic conditions. This selected split point creates two child nodes, and the process iteratively continues, splitting each child node further until no additional

⁷To calculate the classification accuracy, sensitivity, and specificity, a classification threshold is required. We define this threshold as the rate of respondents indicating that future conditions will improve.

division significantly improves prediction accuracy.

To formalize the regression tree methodology in our context, let Y represent the dependent variable capturing individuals' perceptions of future economic conditions, and $X = \{X_1, X_2, \dots, X_p\}$ denote the set of p predictor variables, which include both microeconomic and macroeconomic factors. The goal of the regression tree algorithm is to partition the data into subsets that are as homogeneous as possible with respect to Y , while using binary splits on the predictor variables in X (Loh, 2011; Hastie, 2009; Rokach and Maimon, 2005). Specifically, for each node in the tree, we evaluate all possible binary splits on each X_j and select the one that maximizes the reduction in variance for Y , often referred to as the “information gain” or “reduction in impurity”.

Mathematically, the objective function for selecting the optimal split at a given node is given by:

$$\Delta I = I(\text{parent}) - \left[\frac{N_L}{N} I(\text{left child}) + \frac{N_R}{N} I(\text{right child}) \right] \quad (3.3)$$

where I represents an impurity measure, typically variance for regression trees (other metrics like Gini impurity or entropy are used in classification). N_L and N_R are the sample sizes of the left and right child nodes, respectively, and N is the total sample size at the parent node. The split that maximizes ΔI is selected, and the process is repeated recursively at each child node until reaching a stopping criterion, such as a minimum node size or a threshold for the reduction in impurity.

A key advantage of this approach is its robustness against issues like heteroskedasticity and endogeneity, which can affect traditional econometric models. Additionally, unlike Gaussian models, the regression tree technique accommodates a large number of variables, offering the flexibility needed to handle complex datasets and capture intricate relationships between predictors and the dependent variable.

The dependent variable captures the types of future economic expectations based on Afrobarometer survey question 7, which offers five single-choice options we try to predict: (1) *Much worse*, (2) *Worse*, (3) *Same*, (4) *Better*, and (5) *Much better*⁸. Multiple factors can shape individuals' perceptions of their country's economic fu-

⁸We exclude the two additional options for respondents who either respond “*Don't know*” or “*Refuse to answer*”.

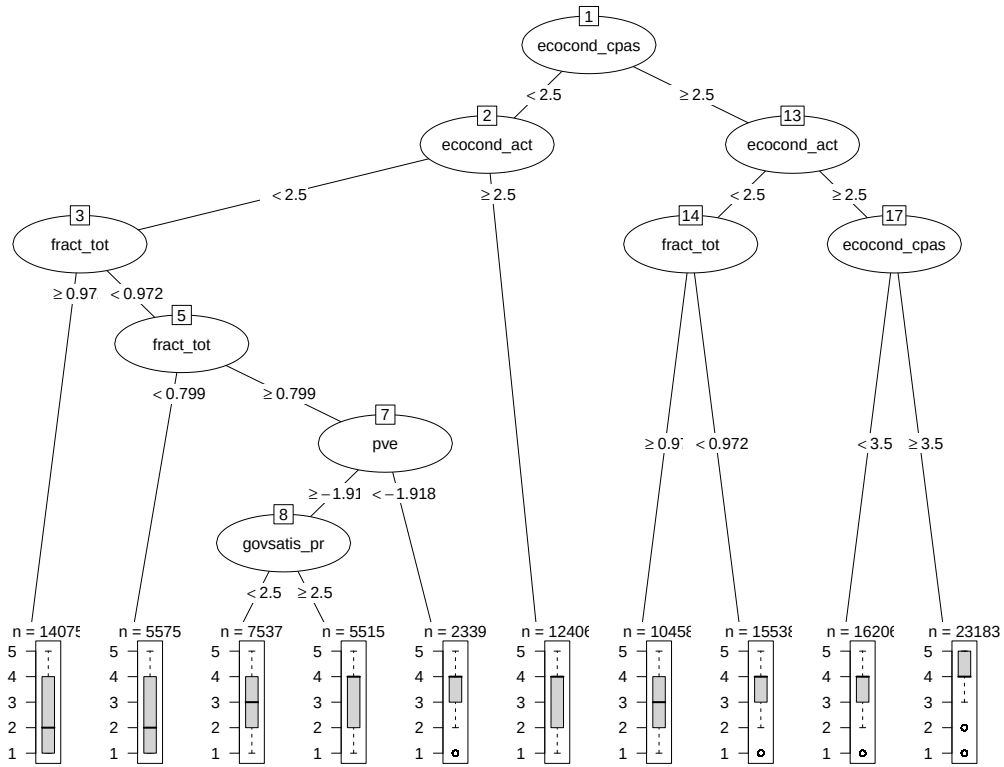


Figure 3.3: Prediction of future economic conditions in the country

Note : *ecocond_cpas*: Pass country's condition, *ecocond_act*: Country's present economic condition, *fract_tot*: Ethno-linguistic and religious fragmentation, *pve*: Political Stability and Absence of Violence/Terrorism, *govsatis_pr*: Government satisfaction (satisfaction with president).

ture.

To construct the regression tree, we introduce a wide array of variables to capture the maximum potential influences on respondents' answers. In addition to the variables already included in the analysis, we incorporate factors used in calculating key indicators, such as measures of ethnic, linguistic, and religious fragmentation⁹. A composite variable is also constructed to summarize these three dimensions of fragmentation.

Moreover, lagged values of the macroeconomic variables listed in Table 3.2 are introduced to reflect both current and prior economic conditions, as these are likely to influence individuals' expectations. In total, the algorithm includes 61 variables across microeconomic and macroeconomic dimensions, forming a comprehensive foundation for the predictive model.

⁹For calculation methods, refer to Posner (2004); Fearon and Laitin (2003).

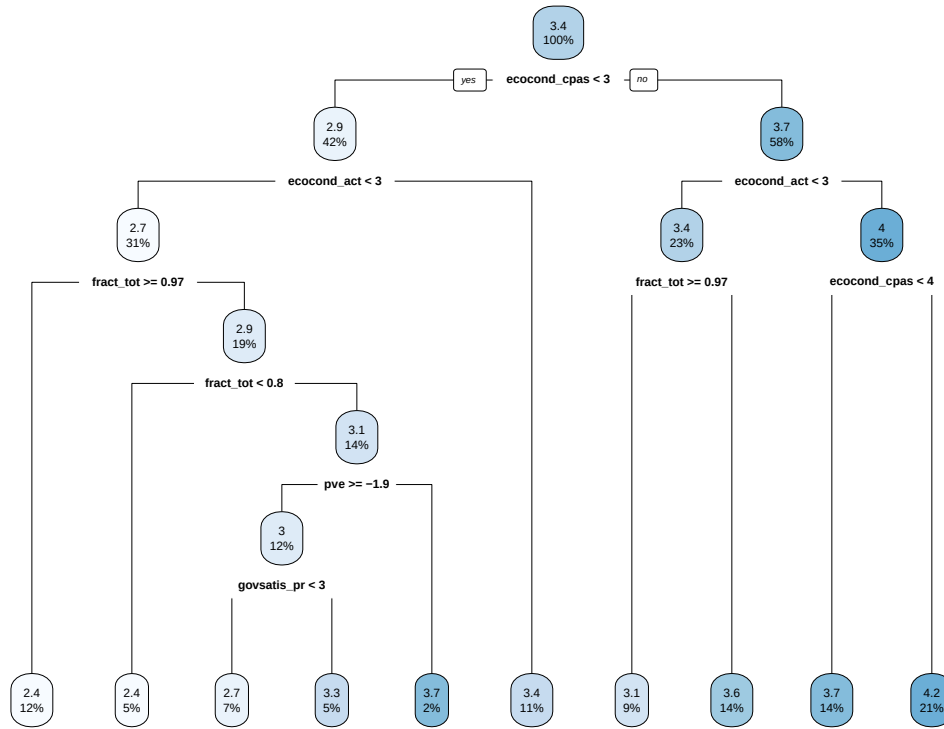


Figure 3.4: Prediction of future economic conditions in the country

Note : *ecocond_cpas*: Pass country's condition, *ecocond_act*: Country's present economic condition, *fract_tot*: Ethno-lingustic and religious frangmentation, *pve*: Political Stability and Absence of Violence/Terrorism.

The results of the regression tree are shown in Figures 3.3 and 3.4.¹⁰ Figure 3.3 illustrates the distribution of the population, while Figure 3.4 shows the predicted values based on the combinations of variables and classified sub-populations. For each of these graphs, we limit our algorithm to 10 nodes, resulting in end nodes at a maximum of ten¹¹. These terminal nodes are nodes 4, 6, 9, 10, 11, 12, 15, 16, 18, and 19.

Nodes 4 and 6 in Figure 3.3 predict, on a scale of 1 to 5, a value of 2.4, suggesting that future economic conditions will not be favorable. The paths leading to these

¹⁰We use the *rpart* package from software R to perform the regression tree.

¹¹We fix the regression tree algorithm at 10 nodes, because we aim to balance model complexity with interpretability. Trees with a high number of nodes can become difficult to interpret, as they over-segment the population and increase the risk of overfitting to the training data. By limiting the tree to 10 nodes, we ensure that the model remains relatively simple yet informative enough to capture key trends. This restriction also serves as a form of pruning, maintaining the sub-population sizes at a statistically meaningful level and avoiding branches based on small sample sizes, which could compromise result robustness. Thus, by stopping the algorithm at 10 nodes, we achieve a methodologically sound compromise between predictive accuracy and readability of the results, in line with best practices for large dataset analyses.

terminal nodes are characterized by sub-populations with poor past and present living conditions and high levels of ethnolinguistic and religious fragmentation. These sub-populations contain 14,075 observations for node 4 and 5,575 for node 6. The median of this sub-population is 2, meaning that 50% of this group has values for the target variable below 2. In contrast, nodes 11, 16, 18, and 19 predict values of 3.7, 3.6, 3.7, and 4.2, respectively. These values indicate that future economic conditions for these sub-populations are expected to improve. The variables conditioning this positive outlook include favorable past and present economic conditions, low levels of ethnolinguistic and religious fragmentation, and a high degree of political stability and absence of violence. The remaining terminal nodes predict values between 2.7 and 3.4, suggesting that the country's future economic conditions will remain unchanged. This stationary projection is explained by stable past and present economic conditions, moderate levels of fragmentation, and relatively fragile political stability.

We observe that past and present economic conditions play a critical role and appear multiple times in the regression tree. Additionally, Table 3.A2 shows a strong correlation between future economic conditions and past and present conditions. For this reason, we re-estimate the regression tree without including these variables, to identify other discriminating factors beyond those defining past and present economic conditions. The results of this adjusted model are recorded in Figures 3.5 and 3.6. Table 3.5 presents the distribution of classified sub-populations, while Figure 3.6 provides the predicted values in each of these sub-populations, conditioned by the combinations of variables used in generating these groups.

The combinations of variables that predict unfavorable future economic conditions are primarily associated with low levels of individual economic satisfaction, rising costs of living, limited national development, relatively high societal fragmentation, and dissatisfaction with the President's policies. In contrast, when individuals report experiencing better economic conditions and show alignment with the President's policies, the model predicts more favorable future economic prospects for these individuals. Where variable combinations are moderate—neither strongly positive nor negative—the model suggests that future economic conditions are likely to remain unchanged.

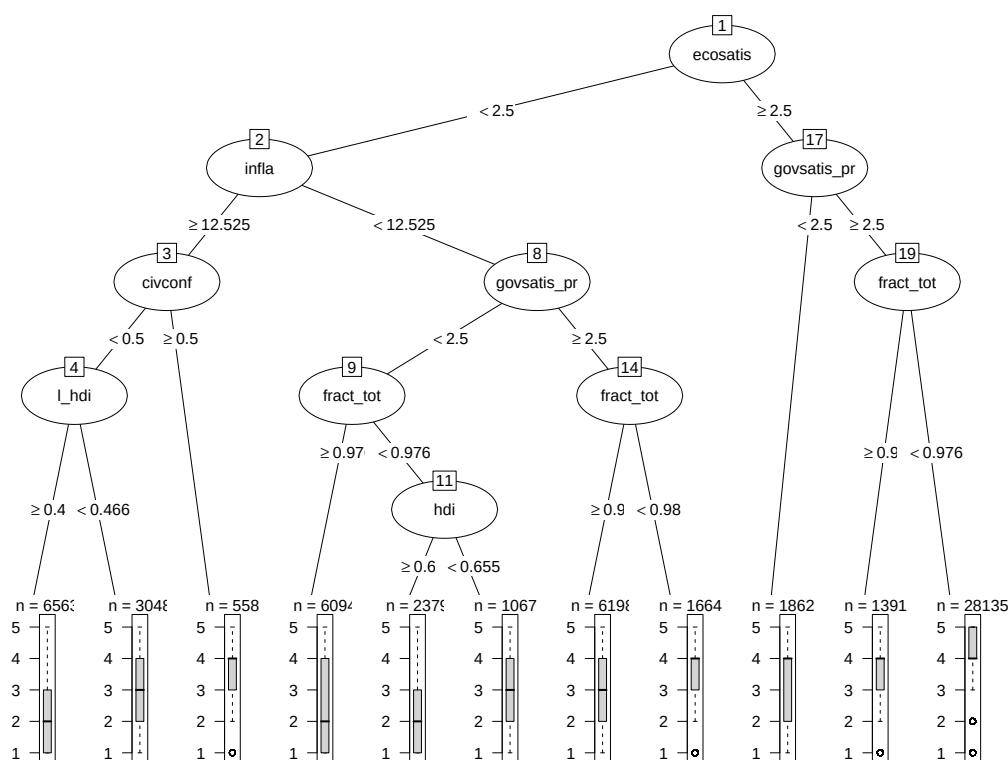


Figure 3.5: Prediction of future economic conditions in the country without the past and present economic conditions variables

Note : *fract_tot*: Ethno-linguistic and religious frangmentation, *pve*: Political Stability and Absence of Violence/Terrorism, *govsatis_pr*: Government satisfaction (satisfaction with president), *infla*: inflation rate, *civconf*: Conflit and violence, *l_hdi*: Human Development Index of the year before the survey, *hdi*: Human Development Index, *ecosatis*: Present living conditions.

Interestingly, these new variables seem to act as substitutes for the variables presented in Figures 3.3 and 3.4. For example, Table 3.A2 shows the correlation matrix between various predictors. The correlation between “ecocond_cpas” (Past country’s conditions) and “ecosatis” (Present living conditions) is 28%, indicating a moderate but significant relationship between past national conditions and current personal satisfaction with living conditions.

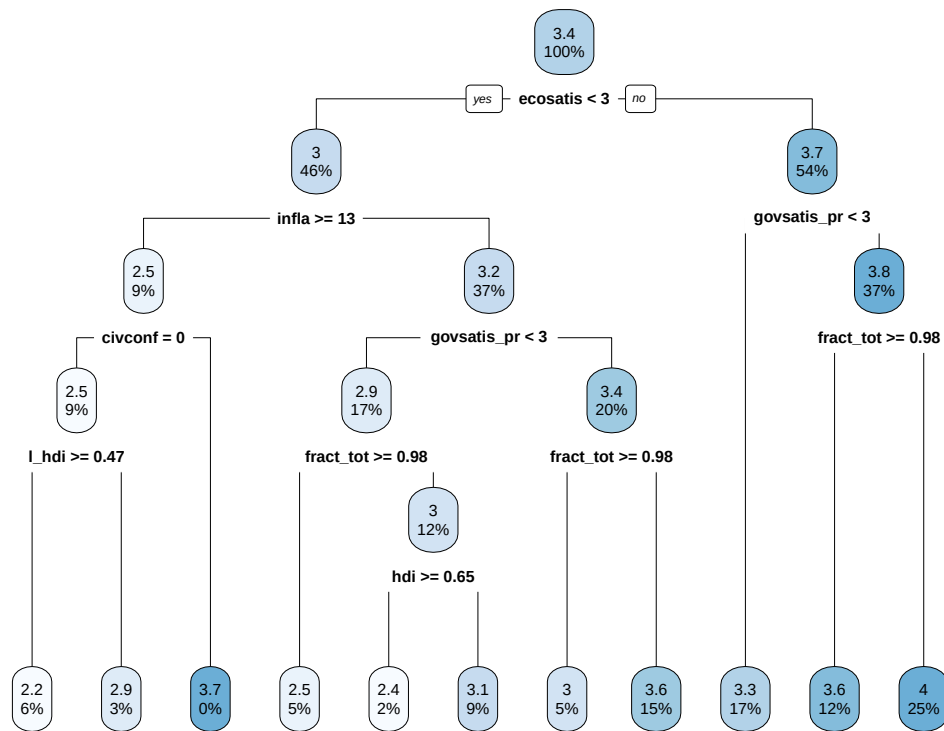


Figure 3.6: Prediction of future economic conditions in the country without the past and present economic conditions variables

Note : *fract_tot*: Ethno-linguistic and religious frangmentation, *pve*: Political Stability and Absence of Violence/Terrorism, *govsatis_pr*: Government satisfaction (satisfaction with president), *infla*: inflation rate, *civconf*: Conflit and violence, *l_hdi*: Human Development Index of the year before the survey, *hdi*: Human Development Index, *ecosatis*: Present living conditions.

3.6 Conclusion

This study aims to explore opinions about future economic conditions in sub-Saharan African economies and forecast expectations regarding economic conditions in sub-Saharan Africa by accounting for both macroeconomic and microeconomic factors. Utilizing Afrobarometer survey data and various macroeconomic databases, we analyze individuals' perceptions of past, present, and future economic conditions. An interesting paradox emerges from this analysis, which we term the "African Optimism Paradox". Despite the fact that the majority of Africans have experienced challenging economic conditions in the past and continue to assess their current living conditions as unfavorable, they remain highly optimistic about their country's economic future.

Our results show that optimistic perceptions of future economic conditions are strongly influenced by past and present economic factors, as well as institutional variables. Macroeconomic stability, ethnolinguistic and religious fragmentation, and the quality of institutions play a crucial role in shaping individuals' views on the future. In particular, the actions of the governments concerning price stability and employment are major determinants of perceptions about the economic outlook.

Using a hierarchical regression approach and decision tree techniques, we predict individual perceptions of future economic conditions based on their past and present living standards, as well as on the institutional and political stability of their country. These predictions reveal that favorable past and present economic conditions, combined with low ethnic and religious fragmentation and political stability, lead to optimistic forecasts by individuals. Conversely, unfavorable living conditions and high fragmentation, along with dissatisfaction with government policies, lead to pessimistic expectations.

This study not only confirms the role of macroeconomic factors in shaping economic expectations, but also highlights the importance of institutional conditions and social cohesion in determining whether individuals are optimistic or pessimistic about the future. It also underscores the need to strengthen institutions and promote political stability to improve long-term economic prospects in sub-Saharan Africa.

In conclusion, our findings emphasize the need to design targeted public policies to ensure that current and future economic conditions align with the expectations of the population, particularly in the context of high ethnolinguistic and religious fragmentation. To foster justified and sustainable optimism, policymakers can implement reforms aimed at improving present living conditions and strengthening institutional and macroeconomic stability.

APPENDIX

A Tables

Table 3.A1: Descriptive statistics by country

Country Name	Code	N	futurel	urbnr	age	gender	education	ecocond	cpas	ecosatis	govperf	polpart	polinter	medexp	livedpoverty	democ	satis	govsatis	trust	inst	hdi	qi	polity2	1	civconf	debt	infla
Burundi	BDI	2149	0.41	0.16	37.52	0.48	2.13	2.56	2.55	1.81	2.49	0.66	0.21	1.66	2.82	3.02	1.57	0.41	-1.32	6.00	0.00	0.00	38.61	11.30			
Benin	BEN	3275	0.70	0.47	36.16	0.49	2.31	2.72	2.56	1.92	2.11	0.95	0.78	1.43	2.51	2.63	1.32	0.50	-0.33	7.00	0.00	0.00	36.85	0.34			
Burkina Faso	BFA	1887	0.73	0.27	36.87	0.48	1.84	3.11	3.04	2.00	2.24	0.69	0.72	1.46	2.61	2.80	1.58	0.41	-0.47	3.33	0.00	0.00	33.70	1.90			
Botswana	BWA	2958	0.58	0.66	37.68	0.49	4.34	3.07	2.51	2.11	1.83	0.87	1.88	0.97	2.80	2.63	1.45	0.70	0.84	8.00	0.00	0.00	17.12	5.03			
Ivory Coast	CIV	2999	0.70	0.53	35.49	0.48	3.36	3.02	2.83	2.02	2.25	0.72	1.47	1.52	2.21	2.53	1.48	0.47	-0.78	4.00	0.00	0.00	45.00	1.24			
Cameroon	CMR	2485	0.63	0.54	32.82	0.46	4.56	2.95	2.95	2.06	2.30	1.01	1.75	1.59	2.13	2.51	1.31	0.55	-1.02	4.00	0.00	0.00	25.80	1.93			
Cape Verde	CPV	2882	0.72	0.69	37.17	0.49	3.88	2.88	2.81	2.05	1.63	0.82	2.12	0.64	2.26	2.67	1.33	0.64	0.75	10.00	0.00	0.00	107.09	1.71			
Algeria	DZA	1877	0.68	0.65	38.21	0.48	4.00	3.16	3.22	1.97	1.12	0.86	2.42	0.35	2.53	2.63	1.08	0.75	-0.87	2.00	0.00	0.00	8.14	3.97			
Egypt	EGY	1829	0.50	0.45	36.97	0.48	4.02	2.63	2.72	1.77	0.96	1.03	2.17	0.65	2.35	2.49	1.57	0.69	-0.93	4.00	0.00	0.00	86.07	9.88			
Gabon	GAB	2174	0.36	0.80	33.76	0.49	4.90	2.43	2.65	1.58	1.74	1.02	2.28	1.90	1.64	2.04	0.85	0.70	-0.45	3.00	0.00	0.00	53.54	1.13			
Ghana	GHA	5531	0.68	0.53	36.98	0.48	3.45	2.90	2.49	2.01	1.63	0.90	1.30	0.61	2.92	2.51	1.43	0.58	-0.03	8.00	0.00	0.00	62.24	11.27			
Guinea	GIN	3112	0.59	0.35	40.71	0.48	2.21	2.69	2.53	1.71	2.42	0.80	0.65	1.75	2.20	2.51	1.42	0.45	-1.05	4.00	0.00	0.00	37.90	9.67			
Gambia	GMB	1011	0.82	0.62	36.04	0.49	3.19	3.21	3.51	2.27	2.40	0.94	1.33	0.97	2.74	2.80	1.89	0.46	-0.53	3.00	0.00	0.00	73.39	6.52			
Kenya	KEN	4752	0.47	0.39	35.58	0.46	4.21	2.65	2.50	1.71	2.05	0.98	1.48	1.00	2.55	2.60	1.47	0.57	-0.91	8.62	0.00	0.00	47.69	9.41			
Liberia	LBR	1800	0.57	0.50	35.17	0.48	3.71	2.92	2.91	1.72	2.15	0.77	0.90	1.55	2.61	2.39	1.22	0.43	-0.67	6.00	0.00	0.00	21.84	7.30			
Lesotho	LSO	2294	0.75	0.33	41.93	0.50	3.30	2.76	2.13	1.85	2.33	1.08	0.79	1.50	2.22	2.33	1.41	0.51	-0.01	8.00	0.00	0.00	36.21	5.49			
Morocco	MAR	2455	0.58	0.64	35.56	0.46	4.22	3.06	3.17	1.70	1.40	0.85	2.23	0.58	2.32	2.18	1.01	0.66	-0.29	4.00	0.00	0.00	63.08	1.78			
Madagascar	MDG	2607	0.31	0.25	39.45	0.47	3.18	2.49	2.41	1.69	2.08	0.63	0.65	1.54	1.71	2.44	1.16	0.51	-0.71	5.27	0.00	0.00	34.89	6.53			
Mali	MLI	3396	0.74	0.25	39.55	0.49	1.57	2.98	2.63	1.93	2.04	0.84	0.78	1.19	2.22	2.63	1.55	0.42	-0.93	3.44	0.00	0.00	29.45	2.56			
Mozambique	MOZ	4648	0.77	0.38	33.60	0.49	3.41	3.26	2.98	2.19	2.24	0.87	1.15	1.21	2.36	3.06	1.72	0.43	-0.60	5.00	0.00	0.00	70.96	3.35			
Malawi	MWI	4299	0.43	0.21	34.47	0.47	2.78	2.27	2.37	1.88	3.10	1.01	0.49	1.40	2.48	2.24	1.36	0.46	-0.34	6.00	0.00	0.00	46.69	21.64			
Namibia	NAM	3199	0.68	0.49	35.47	0.50	4.33	3.20	3.25	1.98	1.69	0.83	1.78	0.84	2.87	2.89	1.63	0.63	0.46	6.00	0.00	0.00	30.36	6.07			
Niger	NER	2940	0.71	0.20	39.17	0.47	1.37	3.01	3.10	2.08	2.01	1.07	0.44	1.74	2.65	2.79	1.66	0.35	-0.82	6.00	0.00	0.00	34.87	1.62			
Nigeria	NGA	5791	0.77	0.45	32.55	0.50	4.41	2.80	3.08	1.74	1.59	1.05	1.55	1.05	2.10	2.23	1.15	0.52	-1.40	4.84	0.62	0.62	13.06	11.87			
Sudan	SDN	1798	0.32	0.40	34.04	0.48	5.07	1.96	2.62	1.44	1.93	0.91	2.03	1.16	2.10	2.13	1.07	0.49	-1.61	4.00	0.45	0.45	94.64	51.12			
Senegal	SEN	3024	0.71	0.53	37.34	0.48	2.70	2.94	2.97	1.98	2.17	1.11	1.59	1.52	2.76	2.64	1.55	0.49	-0.12	7.00	0.00	0.00	42.52	0.34			
Sierra Leone	SLE	2418	0.73	0.42	36.64	0.47	3.22	3.00	2.78	1.99	2.17	0.91	0.64	1.22	2.79	2.49	1.69	0.41	-0.60	7.00	0.00	0.00	41.85	10.23			
Sao Tome and Principe	STP	1834	0.78	0.66	35.32	0.49	4.02	3.07	2.87	2.20	1.51	0.86	1.74	0.74	1.97	2.47	1.18	0.59	-0.19	10.00	0.00	0.00	83.86	6.71			
Swaziland	SWZ	2834	0.63	0.22	36.06	0.47	4.34	2.86	2.96	2.00	2.12	0.74	1.75	1.16	1.85	2.38	1.44	0.58	-0.39	9.00	0.00	0.00	18.31	5.13			
Togo	TGO	2675	0.62	0.43	34.86	0.46	3.54	2.64	2.37	1.77	2.17	0.80	0.96	1.87	1.83	2.28	1.19	0.48	-0.64	2.00	0.00	0.00	61.82	0.50			
Tunisia	TUN	1699	0.49	0.68	41.05	0.46	3.98	2.25	2.59	1.46	0.86	1.09	2.05	0.67	2.15	2.11	1.23	0.73	-0.36	6.49	0.00	0.00	51.99	6.30			
Tanzania	TZA	5467	0.31	0.35	38.33	0.47	3.22	2.58	2.23	1.82	2.47	0.98	1.07	1.18	2.89	2.78	1.64	0.52	-0.44	0.25	0.00	0.00	33.12	9.75			
Uganda	UGA	4501	0.41	0.19	35.43	0.46	3.37	2.57	2.66	1.76	2.18	0.94	0.69	1.29	2.55	2.65	1.64	0.50	-0.76	1.00	0.00	0.00	30.43	9.22			
South Africa	ZAF	5919	0.52	0.69	38.66	0.50	4.58	2.83	2.97	1.78	1.71	0.90	2.28	0.73	2.43	2.38	1.28	0.68	0.01	9.00	0.00	0.00	45.21	4.69			
Zambia	ZMB	2758	0.51	0.45	34.90	0.48	3.74	2.93	2.95	1.87	1.82	0.89	1.13	1.15	2.73	2.45	1.44	0.58	-0.09	6.66	0.00	0.00	42.00	7.08			
Zimbabwe	ZWE	4647	0.43	0.38	38.05	0.48	4.31	2.76	2.59	1.90	1.92	0.94	1.23	1.35	2.06	2.50	1.53	0.52	-1.22	2.67	0.00	0.00	53.87	1.74			

Table 3.A2: Matrix of correlations

Variables	future1	urban	age	gender	education	ecocond	cpas	ecosatis	govperf	polpart	polinter	medexp	livedpoverty	democ	satis	govsatis	trust	inst	hdi	qi	polty2	l	ci	conf	debt	infla
Future economic condition	1.000																									
Urban (=1)	0.001	1.000																								
Age	-0.035	-0.069	1.000																							
Gender	0.012	0.010	-0.100	1.000																						
Education	-0.040	0.322	-0.241	-0.098	1.000																					
Past country's conditions	0.313	0.006	-0.020	-0.004	-0.002	1.000																				
Present living conditions	0.244	0.068	-0.080	0.009	0.126	0.280	1.000																			
Government performance	0.220	-0.034	-0.007	0.005	-0.041	0.237	0.235	1.000																		
Political Participation	-0.001	-0.201	0.128	-0.137	-0.070	-0.009	-0.055	0.033	1.000																	
Political interest	-0.006	0.044	0.019	-0.170	0.169	-0.014	0.001	0.002	0.181	1.000																
Media exposure	0.006	-0.465	-0.160	-0.093	0.567	0.035	0.181	-0.002	-0.130	0.176	1.000															
Lived Poverty Index	-0.129	-0.190	0.052	0.006	-0.246	-0.158	-0.297	-0.123	0.164	-0.013	-0.319	1.000														
Satisfaction with democracy	0.180	-0.067	0.044	0.007	-0.106	0.185	0.160	0.260	0.051	0.010	-0.075	-0.132	1.000													
Government satisfaction	0.230	-0.089	0.046	0.021	-0.131	0.235	0.182	0.371	0.064	-0.036	-0.093	-0.091	-0.053	1.000												
Trust in institution	0.160	-0.111	0.066	-0.010	-0.118	0.156	0.126	0.285	0.082	-0.003	-0.101	-0.091	0.291	0.413	1.000											
Human Development Index	-0.057	0.237	0.008	0.004	0.291	-0.007	0.032	-0.039	-0.232	0.005	0.399	-0.272	-0.077	-0.023	-0.103	1.000										
Institutional quality	0.045	0.149	0.032	0.004	0.039	0.072	0.002	0.078	-0.042	-0.009	0.136	-0.156	0.107	0.122	0.033	0.008	1.000									
Level of democracy	0.068	0.090	0.033	0.010	-0.052	0.031	-0.017	0.037	-0.027	0.010	-0.025	-0.042	0.107	0.122	0.036	0.012	0.075	1.000								
Conflict and violence (Last year)	0.042	0.000	-0.057	0.006	0.097	-0.027	0.055	-0.027	-0.053	0.040	0.069	-0.042	-0.091	-0.055	-0.075	-0.080	-0.041	-0.338	-0.024	1.000						
Government debt	-0.026	0.088	-0.005	0.003	0.055	-0.043	-0.021	0.021	-0.060	-0.025	0.107	-0.091	-0.049	-0.010	-0.010	0.017	0.120	0.148	0.104	-0.138	1.000					
Inflation	-0.116	-0.075	-0.033	-0.000	0.063	-0.149	-0.070	-0.109	0.072	0.024	-0.043	-0.024	0.024	-0.092	-0.076	-0.100	-0.251	-0.108	0.234	0.125	1.000					

Table 3.A3: Definition of microeconomic variables

Variable	Question and Answers (afrobarometer) / Definition	Sources
Future country's economic condition	Q7. Looking to the future, would you say that the economic conditions in this country will be better or worse in a 12-month period? Answers: 1: Much worse, 2: Worse, 3: Same, 4: Better, 5: Much better, 9: Don't know, 8: Refused. Recoded into binary: 1 if respondent chooses 4 or 5 (better); 0 otherwise (modalities 1, 2, 3)	Afrobarometer survey
Urban (=1)	urbur. urban or rural primary sampling unit	Afrobarometer survey
Age	Q1. age	Afrobarometer survey
Gender	Q101. Gender. Answers: 1: Male, 2: Female. Recoded into 0: Male, 1: Female	Afrobarometer survey
Education	Q97. Education of respondent	Afrobarometer survey
Past country's condition	Q6. Looking back, how do you rate economic conditions in this country compared to twelve months ago? Answers: 1: Much worse, 2: Worse, 3: Same, 4: Better, 5: Much better, 9: Don't know	Afrobarometer survey
Present living conditions	Q4a. In general, how would you describe: The present economic condition of this country? Answers: 1: Very Bad, 2: Fairly Bad, 3: Neither good nor bad, 4: Fairly Good, 5: Very good	Afrobarometer survey

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Table 3.A3 – Continued from previous page

Variable	Question and Answers (afrobarometer) / Definition	Sources
Gouvernment performance	This index captures for an individual's opinion on the government's performance in terms of job creation (Q56c: handling creating jobs) and price stability (Q56d: handling keeping prices stable). Answers to Q56c and Q56d: 1: Very bad, 2: Rather badly, 3: Rather well, 4: Very good, 9: Don't know / Didn't hear enough about it	Construction by the Authors, Combined Q56c and Q56d into Government Performance Index using Cronbach's Alpha, following Hutchison and Johnson (2017); Hutchison (2011); Hutchison and Johnson (2011)

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Table 3.A3 – Continued from previous page

Variable	Question and Answers (afrobarometer) / Definition	Sources
Political participation	This index assesses for a given individual, his or her level of participation in political activities in the 12 months preceding the survey, mainly participation in a community meeting (Q21a: expects a community meeting) and meeting with others to discuss a problem (Q21b: join others to raise an issue). Answers of Q21a and Q21b: 4: Often; 3: A few times; 2: Once or twice; 1: I would have done it if I'd had the chance; 0: I'll never do it; 9: Don't know.	Construction by the Authors, Combined Q21a and Q21b into Political participation Index using Cronbach's Alpha, following Hutchison and Johnson (2017); Hutchison (2011); Hutchison and Johnson (2011)

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Table 3.A3 – *Continued from previous page*

Variable	Question and Answers (afrobarometer) / Definition	Sources
Media exposure	Media exposure measures the frequency with which individuals use certain sources of information, including radio (Q12a), television (Q12b), print media (Q12c) and the Internet (Q12d), to stay informed about current events. Answers to Q12a-Q12d: 4: Every day; 3: A few times a week; 2: A few times a month; 1: Less than once a month; 0: Never; 9: Don't know	Construction by the Authors, Combined Q12a-Q12d into Media exposure Index using Cronbach's Alpha, following Hutchison and Johnson (2017) ; Hutchison (2011) ; Hutchison and Johnson (2011)

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Table 3.A3 – Continued from previous page

Variable	Question and Answers (afrobarometer) / Definition	Sources
Lived Poverty Index	This index measures the frequency of certain economic difficulties faced by the household in terms of food (Q8a: Gone without enough food to eat?), lack of drinking water (Q8b: Gone without enough clean water for home use?) and lack of medical care (Q8c: Gone without medicines or medical treatment?). Answers to Q8a-Q8c: 0: Never; 1: Just 1 or 2 times; 2: A few times; 3:Several times; 4:Always; 9:Don't know	Construction by the Authors, Combined Q12a-Q12d into Lived Poverty Index using Cronbach's Alpha, following Hutchison and Johnson (2017) ; Hutchison (2011) ; Hutchison and Johnson (2011)
Satisfaction with democracy	Q36. Satisfaction with democracy	Construction by the Authors, following Hutchison and Johnson (2017) ; Hutchison (2011) ; Hutchison and Johnson (2011)

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Table 3.A3 – *Continued from previous page*

Variable	Question and Answers (afrobarometer) / Definition	Sources
Gouvernment satisfastion	This index measures the degree of satisfaction with the activities carried out by the president (Q58a. performance: president), the deputy in the national assembly (Q58b. performance: mp/national assembly rep) and the prefectoral / municipal councillor (Q58c. Your prefectoral / municipal councillor). Answers to Q58a-Q58c: 7: Not Applicable (only for question Q58d); 1:Strongly disagree; 2:Disagree; 3:Agree; 4:Strongly agree; 9:Don't know / Haven't heard enough about it	Construction by the Authors, Combined Q58a-Q58c into Gouvernment satisfastion Index using Cronbach's Alpha, following Hutchison and Johnson (2017) ; Hutchison (2011) ; Hutchison and Johnson (2011)

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Table 3.A3 – Continued from previous page

Variable	Question and Answers (afrobarometer) / Definition	Sources
Institution trust	This index assesses, for a given individual, his or her level of trust in political institutions, such as the President of the Republic (Q43a), the National Assembly (Q43b), the Independent Electoral Commission (Q43c), the ruling party (Q43e) and the opposition political parties (Q43f). Answers to Q43a-Q43f: 0: Not at all confident; 1:Just a little confident; 2:Partially confident; 3:Very confident; 4:Don't know/Never heard of it	Construction by the Authors, Combined Q43a-Q12f into Institution trust Index using Cronbach's Alpha, following Hutchison and Johnson (2017) ; Hutchison (2011) ; Hutchison and Johnson (2011)
Political interest	It measures how often an individual discusses political issues when with friends or family (Q13)	Construction by the Authors, following Hutchison and Johnson (2017) ; Hutchison (2011) ; Hutchison and Johnson (2011)

Table 3.A4: Definition of macroeconomic variables

Variable	Definition	Sources
Human Development Index	This index assesses the country's development from three dimensions, including health, education and living standards.	Human Development Data
Institutional quality	This is the average of three governance indicators including the rule of law, the Control of Corruption, the Political Stability and Absence of Violence/Terrorism from last year. The composite measures of governance generated are in units of a standard normal distribution, with mean zero, standard deviation of one, and running from approximately -2.5 to 2.5, with higher values corresponding to better governance. See https://www.worldbank.org/content/dam/sites/govindicators/doc/wgimethodologypaper.pdf	Construction by the Authors, from The World-wide Governance Indicators dataset, 2018 Update
Level of democracy		Polity IV dataset
Conflict and violence		UCDP/PRIO Armed Conflict Dataset
Government debt		International Financial Statistics, International Monetary Fund

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Table 3.A4 – *Continued from previous page*

Variable	Definition	Sources
Inflation	Inflation, consumer prices (annual %)	World Development Indicators, World Bank

B Figures

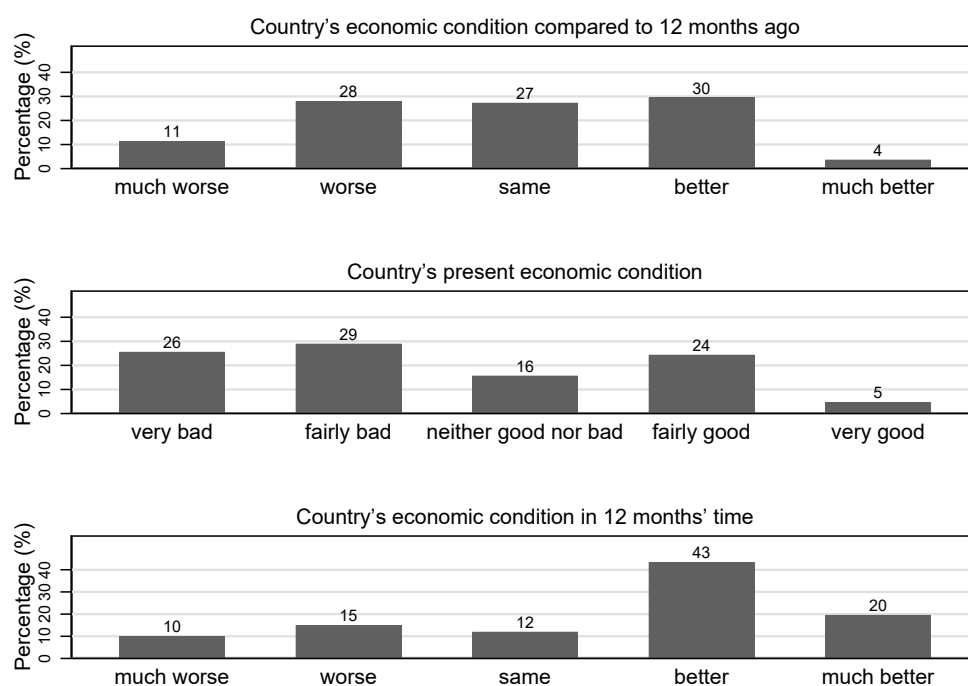


Figure 3.B1: Round 5: Analysis of opinions on past, present and future economic conditions in countries

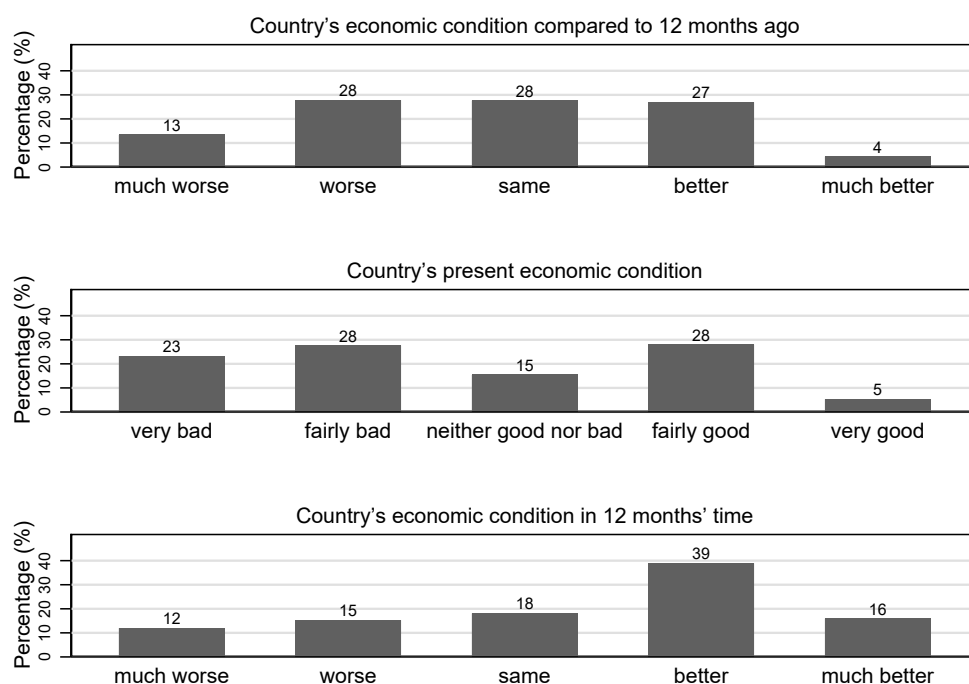


Figure 3.B2: Round 6: Analysis of opinions on past, present and future economic conditions in countries

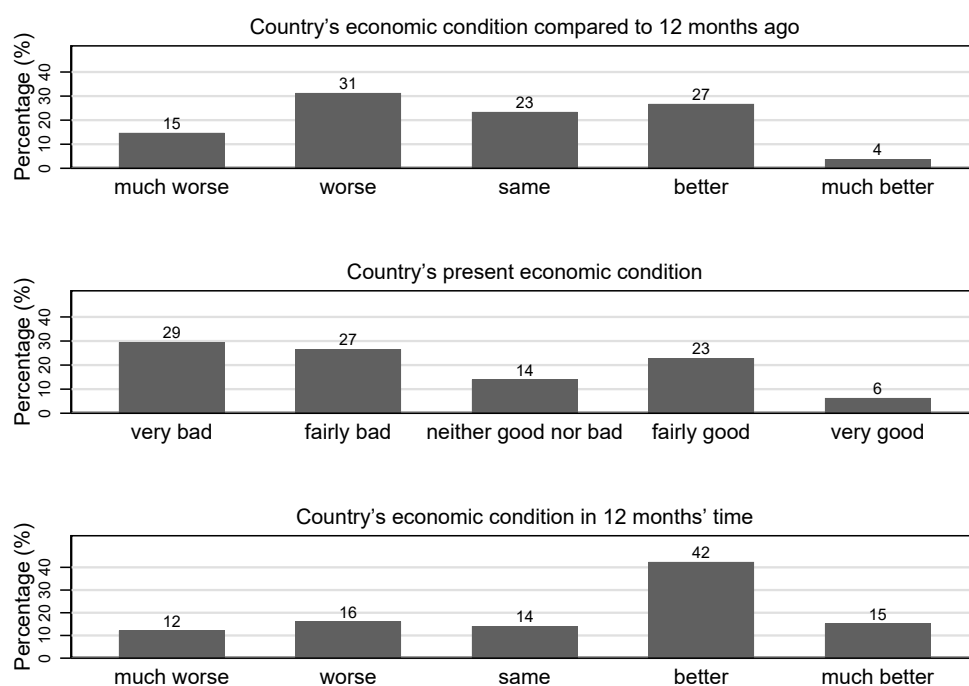


Figure 3.B3: Round 7: Analysis of opinions on past, present and future economic conditions in countries

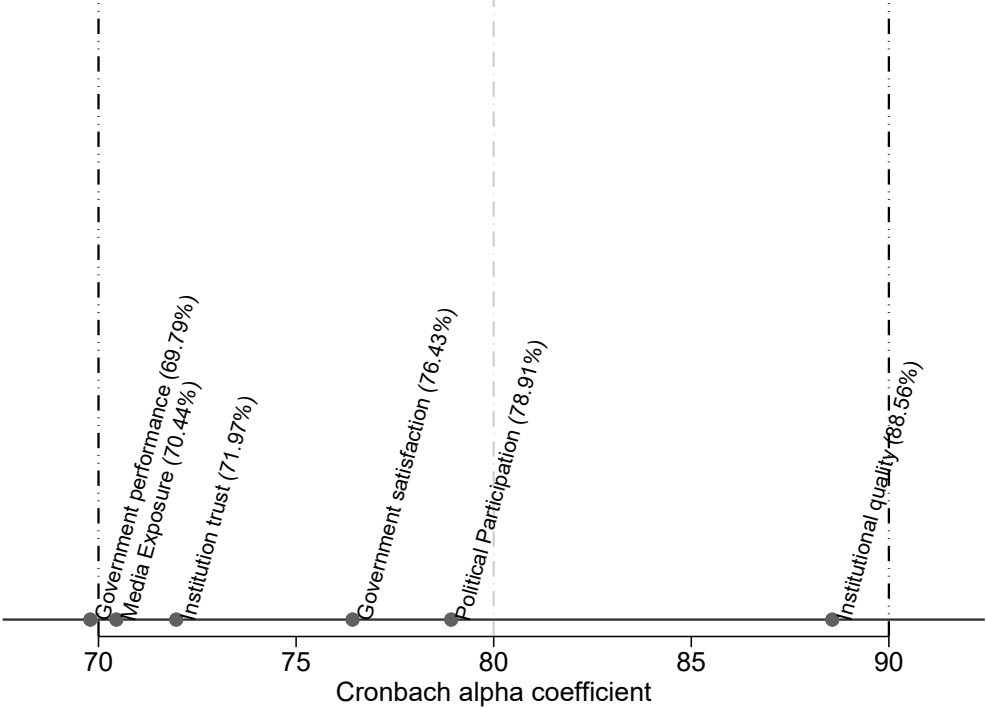


Figure 3.B4: Cronbach Alpha Coefficients

4

Shocks and industrialization in emerging countries: a PVAR approach¹

Abstract: This chapter examines the impact of domestic and foreign macroeconomic shocks on industrial development in emerging countries under uncertainty. Using data from 27 emerging countries from 1980 to 2019, we apply a PVAR approach along with GMM and bootstrap methods to address endogeneity issues. The results show that foreign direct investment (FDI) inflows have a positive and lasting impact on industrialization. However, a positive GDP shock—i.e., a sudden and significant increase in GDP—does not systematically lead to a positive effect on industrialization. Global economic changes, from crises to more open trade policies, and shifts in trade structures and supply chains, influence industrial development of these countries. While there are several transmission channels for these shocks (e.g., the dynamic effects of industrialization, investment, and the rise of the service economy), only the impact of a positive FDI shock consistently emerges as a clear determinant of industrialization. Conversely, openness-related shocks, such as those related to trade and capital account liberalization, do not have a direct effect. Therefore, public policies promoting FDI may significantly contribute to industrial development.

Keywords: Industrialization, Foreign Direct Investment, Macroeconomic Shocks, PVAR, Network and Graph Theory

JEL Codes: O14, F21, F62, C33, C49

¹This chapter is under revision at *The Journal of International Trade and Economic Development*.

4.1 Introduction

Globalization has considerably increased deindustrialization in advanced economies ([Kudina and Pitelis, 2014](#); [Kang and Lee, 2011](#)). At the same time, the industrial sector has become more and more developed and concentrated in emerging countries ([Gereffi, 2019](#)). As a result, these countries have started to play a key role in the global economy. Strongly interconnected with advanced and developing economies, they are a main source of production at the world level.

Emerging countries have therefore started to play a key role in the global value chain ([Gereffi and Sturgeon, 2013](#)). They are significant drivers of consumption-driven economic growth ([Gereffi, 2019](#); [Naughton, 2012](#); [Ross, 2006](#)). Representing nearly 82% of the world's population in 2009, emerging countries also offer the highest concentration of market opportunities ([European Central Bank, 2010](#)). As a result, they attract a considerable amount of investment, including substantial foreign direct investment (FDI) flows ([United Nations Conference on Trade and Development, 2019](#); [World Bank, 2019](#)).

However, with this overall openness, the industrial sector in these countries becomes highly sensitive to various foreign and domestic economic shocks. Additionally, factors affecting these countries also directly impact the global economy through the global value chain. Over the past three decades, successive global crises—including natural disasters, health crises, the 2008 global financial crisis (GFC), and more recently pandemics—have led to increasing instability in FDI, particularly since the 2008 GFC ([Pagliari and Hannan, 2017](#); [Mariana, 2011](#)). Consequently, the effects on industrialization have been evident ([Rodriguez-Clare, 1996](#); [Markusen and Venables, 1999](#)).

While many studies focus on the determinants of industrialization in developed and developing countries, the literature is rather silent on the effect of macroeconomic shocks on industrialization in emerging countries.

This is precisely the focus of this study. Considering that the global economic context is marked by uncertainty, we will assess the effect of macroeconomic shocks on the external (trade, FDI, capital account openness) and internal (service sector, investment, GDP per capita, productivity) determinants of industrialization in emerging countries.

Our study covers 27 emerging countries over the period 1980-2019 using balanced panel data. To carry out this study, we use data from various databases including the World Bank's World Development Indicator (WDI), Penn's World Table (version 9.1, [Feenstra et al. \(2015\)](#)), [Chinn and Ito \(2006\)](#) Capital Account Liberalization Index database ([Chinn and Ito, 2006](#)).

We use a panel vector autoregressive (PVAR) approach focusing on the responses of the industrial sector to different shocks. We orthogonalize each response to identify the effect of one shock at a time, holding other shocks constant. However, it should be noted that the variables used in the study are highly endogenous. To overcome this and isolate the responses to shocks for each variable, we estimate the response functions using GMM with instruments.

In addition, given that the order of variables is important in VAR (vector autoregressive) models, and due to the large number of variables introduced into the system of equations, we determine the order of introduction of variables based on the Granger-Wald causality test and network and graph theory. The network analysis enables us to set up our network causality system and understand how variables influence each other. It also allows us to determine the importance of each variable through centrality indicators. Finally, for the sake of robustness, we estimate our results using a bootstrap approach as well.

The results show that foreign direct investment flows to emerging economies have a positive and persistent impact on industrialization. However, the effects of a positive GDP shock are not systematically translated into a positive effect on industrialization for these same countries. Although there are several transmission channels for these shocks to the industrial sector (dynamic effect of industrialization, investment, service economy), only the effect of a positive FDI shock seems to be truly decisive in the industrialization of emerging economies. Conversely, openness-related shocks (e.g. trade and capital) do not appear to have had a direct effect. Considering the growing size of the industrial sector in emerging economies, the increasingly marked integration of these countries in the world economy, and the importance of global trade volumes, this result suggests that the effects of the openness policies are transmitted rather gradually and may not be captured by a shock model. Conversely, global macroeconomic shocks or public policies favoring

FDI would contribute directly to industrial development. Using a robust PVAR approach, we propose new avenues of research to explore the impact of FDI on emerging economies' industrialization.

The rest of the chapter is divided as follows: Section 4.2 is devoted to literature review; Section 4.3 presents the methodology and data; Section 4.4 reports the results; and Section 4.5 is dedicated for an discussion of the main finding. Finally Section 4.6 concludes.

4.2 Literature review

Industrialization is crucial to a country's economic development (Mohammed, 2019; Ciarli and Di Maio, 2014) (need for industrialization and growth). Different factors influence the development of industrialization. Private investment, access to credit, political stability, and the development of human capital can positively impact industrialization. Capital account openness, natural resources, territorial isolation, inequality, and high public debt can be expected to have a negative effect on industrial development (Haraguchi et al., 2018). Kang and Lee (2011) divide these factors into two categories: external factors (FDI, trade) and internal ones (GDP per capita, agriculture, services). We will further use this classification between external and internal country-level determinants in our study.

4.2.1 External determinants of industrialization

A vast body of literature examines the effects of FDI on industrialization levels. FDI is generally viewed as having a direct impact on the manufacturing sector, influencing employment and the production of goods. Rodriguez-Clare (1996) demonstrate that the establishment of multinationals in a country creates a demand for specialized inputs, which are largely "non-tradable" and essential for producing "headquarter services" that complement production processes in other countries. Consequently, the presence of multinationals alters the demand for workers within local firms, generating additional employment not only through the establishment of multinational operations but also by stimulating growth in domestic firms. The intensity of this impact depends on the strength of the linkages between multinationals and local companies.

Similarly, Markusen and Venables (1999) suggest that FDI's impact on industri-

alization can be evaluated by examining the industrial sector's value-added contribution to GDP. They argue that FDI has two primary effects on industrialization: (1) a competitive effect, resulting from the import or production of substitute goods by multinationals in the local market; and (2) a linkage effect, shaped by the nature and density of connections between companies (local or international) and local suppliers. Increased competition can lead to a higher quantity of goods in the local market, driving down prices and altering the relative productivity of national firms. This competitive effect may lead to the exit of less productive firms from the market. The linkage effect, on the other hand, could prompt local changes in the production structure for goods and services.

These effects seem to be confirmed empirically. [Merlevede et al. \(2014\)](#) detail the effect of FDI on the productivity of local from 1996 to 2015.

The entry of multinationals exerts an immediate effect on productivity, with a lasting positive impact over time. This effect occurs through two main channels: (1) vertical spillovers, which involve the acquisition of foreign technology through employee training, the recruitment and development of multinational employees, and direct technology acquisition; and (2) horizontal spillovers, where former employees of foreign firms apply their enhanced productivity in local companies, often attempting to produce goods similar to those of multinationals, thereby fostering a more competitive market.

Local companies also strive to improve the production of intermediate goods to meet growing local demand, contributing to the development of a more competitive domestic market ([Görg and Greenaway, 2004](#)).

Several studies highlight the positive effects of FDI on industrialization across various regions. Examples include Poland ([Hagemejer and Kolasa, 2011](#)), Belgium ([Belderbos and Van Roy, 2011](#)), Ireland ([Barrios et al., 2005](#)), and China ([Liu, 2002](#)). However, these positive results are contrasted by divergent findings obtained for other countries (e.g., [Nicolini and Resmini, 2010](#) on Bulgaria, Poland, and Romania from 1998-2003, and [Barbosa and Eiriz, 2009](#) on Portugal from 1994-1999). Additionally, some studies report non-significant impacts of FDI on industrialization, such as those by [Harrison and Rodríguez-Clare \(2010\)](#), [Gui-Diby and Renard \(2015\)](#), and [Kaya \(2010\)](#).

Some authors even argue that FDI inflows have exerted a negative impact on domestic firms. This is notably the case for Ghanaian firms between 1991 and 1997, as demonstrated by [Walldkirch and Ofori \(2010\)](#), and for Chinese companies from 2000 to 2003, as highlighted by [Xu and Sheng \(2012\)](#). Similarly, [Görg et al. \(2009\)](#) analyzed FDI in Hungary from 1992 to 2003 and found that the presence of foreign firms had adverse effects on the productivity of local companies.

Thus, a strong inflow of FDI into a country could result in substantial shifts in productivity, employment structure, and overall industrialization outcomes.

Other studies emphasize the influence of a country's openness on its industrialization level. Openness policies can affect the FDI-industrialization relationship through factors such as exchange rate adjustments and tariff liberalization ([Harrison and Rodríguez-Clare, 2010](#); [Kang and Lee, 2011](#)). In a study on the United States, [Sachs et al. \(1994\)](#) found that openness negatively impacted employment in labor-intensive sectors by reducing the demand for unskilled labor. [Dollar et al. \(1993\)](#) observed no direct relationship between OECD countries' openness and industrial growth, attributing a greater role to structural reforms. However, a country's level of development appears to significantly mediate these effects, as [Kozul-Wright and Fortunato \(2019\)](#) observed opposite outcomes for developing countries. This underscores the importance of assessing the internal determinants of industrialization.

4.2.2 Internal determinants of industrialization

Theoretically, an inverse U-shaped relationship exists between income level and manufacturing output ([Clark, 1957](#)). As an economy develops, demand for agricultural and fishing products decreases while demand for manufactured goods rises, peaking until a certain income threshold is reached, after which it declines as the service sector grows. Development policies that prioritize the service sector or agriculture could therefore significantly impact the FDI-industrialization dynamic. For instance, in a country where the service sector outpaces manufacturing in productivity, policies favoring services may inhibit FDI effects on manufacturing, as shown by [Kang and Lee \(2011\)](#).

The structure of the manufacturing sector itself is also a determinant of national productivity. [Guerrieri and Meliciani \(2005\)](#) examine 11 OECD countries from 1992 to 1999, finding that a country's ability to cultivate a competitive service economy

is closely tied to the composition of its manufacturing sector, as certain industries rely intensively on service inputs. This suggests that understanding the interplay between the service sector and industrialization is crucial.

Government intervention further influences industrial development. Policies can create favorable conditions for manufacturing growth. For example, [Kang and Lee \(2011\)](#) find that public investment positively affects industrial development in OECD countries by driving demand in the manufacturing sector. In India, government policies have been instrumental in shaping the industrial landscape, influencing ownership structures, internalization, and locational advantages for foreign investors ([Kumar, 1995](#)).

Additional factors, such as geographic location, also play a role in industrialization. Landlocked countries, for instance, face significant production challenges due to limited access to large markets, restricting their ability to exploit economies of scale ([Sachs et al., 1994](#)).

The interdependence and interaction between internal and external factors underscore the complexity of industrial development. Macroeconomic shocks directly affect the relationship among these factors and industrialization. Additionally, there exists an endogeneity among these variables that warrants careful consideration for a comprehensive analysis.

Nevertheless, the effects of these different factors could be differentiated according to country's development level. Theoretically, income plays a very important role in the structure of the economy and therefore in the share of manufacturing output in a country. There is a U-inverse relationship between income level and manufacturing output ([Clark, 1957](#)). When an economy develops, demand for agriculture and fishing decreases while demand for manufacturing increases. The latter will increase until income reaches a given level but then decline as the share of the service sector increases. Thus, it could be expected that development policies supporting the services sector or agriculture could have an effect on the FDI-Industrialization relationship. If a country has a more productive service sector relative to manufacturing, then its policies may inhibit the effect of FDI on manufacturing. This is due to the inverse relationship between the two sectors ([Kang and Lee, 2011](#)).

The structure of the manufacturing sector would also be one of the determi-

nants of productivity for a country. [Guerrieri and Meliciani \(2005\)](#) study 11 OECD countries over the period 1992-1999, and find that a country's ability to develop a competitive service economy depends on the structure of its manufacturing sector. This is because some manufacturing industries are intensive in the use of these types of services.

Other factors also influence industrialization, such as the country's geographical position. Landlocked countries find it more difficult to increase productivity because of the difficulty of accessing large outlets to evacuate production and exploit economies of scale ([Sachs et al., 1994](#)).

Other studies also highlight the effect of a country's degree of openness on its industrialization level. The openness policies implemented can impact the FDI-Industrialization relationship through exchange rate modification and tariff liberalization ([Harrison and Rodríguez-Clare, 2010](#); [Kang and Lee, 2011](#)). [Sachs et al. \(1994\)](#) through a study of the United States, show that opening up would have a negative effect on employment in the labor sector by reducing unskilled labor. [Dollar et al. \(1993\)](#) find no relationship between the openness of OECD countries and their industrial development. The latter argue that the implementation of structural reforms has a greater effect. These analyses also suggest that the level of development of the country greatly influences these effects as [Kozul-Wright and Fortunato \(2019\)](#) obtain the opposite results for developing countries.

Government actions and policies also play a significant role. Through their policies, the latter can also shape industrial development. In this sense, [Kang and Lee \(2011\)](#) show that government investment has a positive impact on industrial development in OECD countries by stimulating demand in the manufacturing sector. In India, government policies have positively shaped the industrial sector. They appear to have played an important role in the country's industrial development pattern in influencing the ownership configuration, internalization, and location benefits of foreign investors ([Kumar, 1995](#)).

Finally, it should be noted that there is a strong dependence and interaction between internal and external factors of industrial development. Shocks in the macroeconomic environment and economic policies therefore impact the relationship between these different factors and industrialization.

4.3 Methology and data

In this section, we will investigate further the methodology, the data, and our empirical specification.

4.3.1 Methodology

In this study, we employ a Panel Vector Autoregressive (PVAR) model to empirically investigate the effects of various shocks on industrialization. This approach offers several advantages.

Firstly, the PVAR model allows all variables in the system to be treated as endogenous while incorporating panel data techniques to address unobserved heterogeneity, which aligns well with our data structure. Given the interdependence of internal and external factors influencing industrialization (Kang and Lee, 2011), this model enables us to account for the endogenous interactions among these factors that collectively shape the level of industrialization. Additionally, the PVAR framework captures both lagged and contemporaneous effects of shocks, allowing us to explore their temporal dynamics comprehensively. Secondly, using Granger causality within the PVAR setup, we can assess the directional influences among the endogenous variables, offering insights into the causal relationships between factors. Lastly, the study of orthogonalized impulse-response functions (IRFs) provides a detailed view of how specific shocks to explanatory variables propagate over time, thereby elucidating the dynamic effects on industrialization.

Our model specification is as follows:

$$Y_{i,t} = \alpha_0 + \sum_{j=1}^p \alpha_j Y_{i,t-j} + f_i + \epsilon_{it} \quad (4.1)$$

Where i represents the country, t denotes time, p the number of lags, and ϵ_{it} represents random deviations or the error term. f_i captures the fixed effects, which account for country-specific unobserved heterogeneity². Y is a vector of variables that includes industrial development (*Industrialization*), net foreign direct investment inflows (*FDI*), domestic investment (*Investment*), economic development or income (*GDP per Capita*), and the service sector (*Service*)³. We also include productivity of

²The importance of including fixed effects is discussed in subsection 4.3.3.

³The service sector is included for two reasons: (1) to prevent overloading the model with other

the factors of production (*Productivity*), economic and financial openness captured by trade openness (*Trade*), and capital account liberalization (*Capital*). Thus, $Y = \{Industrialization, FDI, Capital, Investment, GDP\ per\ capita, Trade, Service, Productivity\}$. Definitions and sources of each variable are listed in Table 4.1.

Unlike OLS approaches, which examine relationships between variables by capturing variation in observations and factoring in panel structures, VAR methods aim to model dynamic interactions among multiple endogenous variables in a system. VARs focus on identifying significant fluctuations (or "shocks") within variables and their subsequent impacts on others over time. Consequently, a VAR model specification is particularly effective when variables exhibit volatility. Therefore, we focus on variables most susceptible to high volatility, leaving aside relatively stable determinants of industrialization (such as geographic position, institutional stability, and demographics), which, while important, tend to be rigid in the short term and thus are not included in this analysis.

The fixed effects were addressed using the Helmert procedure (see Section 4.3.3). Including fixed effects in the PVAR model can introduce bias in coefficient estimation due to correlations with explanatory variables, particularly with lagged values of the dependent variable.

To mitigate these risks, we apply Helmert's forward orthogonal deviations transformation (Love and Zicchino, 2006; Arellano and Bover, 1995). This procedure removes fixed effects by transforming variables into "deviations from the mean of future observations," defined as:

$$Y_{it}^* = Y_{it} - \bar{Y}_{it} \sqrt{\frac{T_{it}}{T_{it} + 1}},$$

where Y^* is the transformed variable, T_{it} the number of future observations for country i at time t , and $\bar{Y}_{it}$ the average of these future observations.

Finally, the model is estimated using the Generalized Method of Moments (GMM), which addresses endogeneity by employing internal instruments, specifically the lagged values of variables, ensuring unbiased coefficient estimates through GMM.

sectors as endogenous or exogenous control variables, and (2) due to the significant relationship between manufacturing and service sectors as highlighted by Kang and Lee (2011) and Guerrieri and Meliciani (2005).

Table 4.1: Definition of variables

Variable	Definition	Source
Industrialization (log)	Manufacturing, value added (% of GDP) or Employment in industry (% of total employment) (ILO modelled estimate)	WDI, World Bank
FDI	Foreign direct investment, net inflow (% of GDP)	CNUCED
Capital	Degree of the capital account openness	Chinn-Ito Index (KAOPEN)
Investment (log)	Gross fixed capital formation (in % of GDP)	WDI, World Bank
GDP per capita (log)	GDP per capita (constant 2010 dollars)	WDI, World Bank
Trade (log)	Sum of exports and imports of goods and services (in % of GDP)	WDI, World Bank
Service (log)	Services, value added (% of GDP)	WDI, World Bank
Productivity	Total factor productivity	Penn World Table (version 10.01)

4.3.2 Data

We use a sample of 27 emerging countries⁴ over the period 1980–2019. The list of countries is presented in Table 4.4. These countries are central to global industrialization, and as noted in the introduction, the shocks affecting them have implications for the global economy through the value chain. This group of countries is relatively homogeneous in terms of economic and financial systems and industrial development. The homogeneity of the sample will be established in Section 4.3.3.

Data are collected from multiple sources, including the World Bank’s Global Development Indicators (WDI), the Penn World Table (version 10.01, [Feenstra et al. \(2015\)](#)), the United Nations Conference on Trade and Development (UNCTAD) database, and the [Chinn and Ito \(2006\)](#) Capital Account Liberalization Index database.

Data availability limits the sample to 27 countries, with observations beginning in 1980. Data quality for some countries before this period is insufficient, and the PVAR method requires uniformly completed data (balanced panel). We conclude in 2019, as Penn World Table data are available only up to that year.

⁴Our classification is based on the International Monetary Fund’s 2019 classifications, which categorize countries as less developed, emerging markets, or advanced economies. See <https://infrastructuregovern.imf.org/content/dam/PIMA/Knowledge-Hub/dataset/IMFInvestmentandCapitalStockDataset2021.xlsx>.

4.3.3 Statistical and econometric tests and Specification of the Panel VAR

Statistical and econometric tests

Running a the PVAR requires caution, particularly with regard to sample homogeneity, variable stationarity, and the cointegration relationship between variables. This section will study these prerequisites in our sample.

Sample homogeneity

The VAR model is very effective on a homogeneous sample sharing relatively similar dynamics. This is why we introduce country fixed effects using the Helmert procedure to correct the residual heterogeneity of our sample. This procedure preserves the orthogonality between the transformed variables and the lagged explanatory variables (Love and Zicchino, 2006).

Indeed, as we have a simple panel model, we used the Fisher's poolability test to explore the homogeneity of our sample (Ramde, 2017). Hsiao (1986) three-step testing procedure consists of three successive tests to determine the correct specification of the model (Hurlin, 2012).

Table 4.2 summarises the results of the tests. The first step (F1) assesses the overall homogeneity of the model by checking whether the estimated coefficients of the explanatory variables, as well as the constant, are the same for all individuals. In our case, we reject the hypothesis that the model is globally homogeneous. The second step (F2) consists of testing the homogeneity of the estimated coefficients in relation to the explanatory variables. In our case, we reject the null hypothesis that the coefficients are homogeneous. The third test (F3) consists of testing the homogeneity of the constants. In this case, the test does not reject the hypothesis of constant homogeneity. Despite this last result, we were unable to confirm the homogeneity of our sample.

Table 4.3 shows the descriptive statistics for our variables. None of the variables follows the normal distribution for the Jarque Bera probability ($p < 0.000$) showing a significant dispersion. Nevertheless, in the country level analysis (Table 4.4) this dispersion is stable and controlled by the log transformation of our variables. This

normalisation allows us to ensure that the means are high in relation to the standard deviations, implying that the dispersion of the data is centralised around the mean. This is true for all the variables with the exception of the FDI and capital account opening variables which, on the contrary, have a wide dispersion. These two variables seem to explain the non-homogeneity found in the series of tests of the Hsiao procedure. It should be noted, however, that this relative homogeneity is found for industrialization and in services.

The preceding analyses lead us to conclude that the problem of overall heterogeneity (F1) and coefficients heterogeneity (F2) does not stem primarily from the extent of overall heterogeneity, but rather from observations that are widely dispersed over time for each country with regard to the FDI and Capital variables.

Table 4.2: Fisher Poolability Testing

	F1	F2	F3
Value	1.619	1.700	0.937
P-Value	0.000	0.000	0.555

Table 4.3: Descriptive statistics of variables

VARIABLES	N	mean	sd	min	max	skewness (Pr)	kurtosis (Pr)	Normality (Pr)
Productivity	1080	1.012	0.217	0.561	3.273	2.893 (0.000)	22.95 (0.000)	0.000
FDI	1080	2.286	2.737	-10.51	22.82	1.803 (0.000)	11.31 (0.000)	0.000
Capital	1080	-0.150	1.383	-1.927	2.311	0.512 (0.000)	1.983 (0.000)	0.000
Industrialization (log)	1080	2.707	0.402	0.933	3.561	-1.066 (0.000)	5.093 (0.000)	0.000
GDP per capita (log)	1080	8.391	0.709	5.960	10.47	-0.385 (0.000)	3.618 (0001)	0.000
Trade (log)	1080	4.078	0.547	2.446	5.240	-0.470 (0.000)	2.962 (0881)	0.000
Service (log)	1080	3.929	0.171	3.244	4.297	-0.775 (0.000)	4.088 (0.000)	0.000
Investment (log)	1080	3.056	0.258	1.760	3.831	-0.212 (0005)	3.617 (0001)	0.000
Country	27							
Year	40			1980	2019			

Check for multicollinearity

Table 4.A1 reveals a statistically significant correlation between the different variables. Consequently, we performed a variance inflation factor test (Table 4.A2 in the appendix), enabling us to analyze possible multicollinearity. Our data do not really suffer from this multicollinearity, since the VIF calculated value is low (1.35 on average, less than 2.5).

Stationarity: unit root test

Table 4.4: Descriptive statistics by country

Country	Industrialization	FDI	GDP per capita	Trade	Investment	Service	Productivity	Capital
Argentina	2,98 (0,28)	1,71 (1,3)	9,3 (0,17)	3,14 (0,4)	2,85 (0,15)	4,01 (0,09)	0,98 (0,07)	-0,41 (1,22)
Bolivia	2,56 (0,22)	3,11 (3,46)	7,68 (0,21)	4,02 (0,22)	2,78 (0,18)	3,84 (0,08)	0,93 (0,07)	0,32 (0,8)
Botswana	1,73 (0,13)	2,83 (3,26)	8,35 (0,38)	4,61 (0,13)	3,34 (0,13)	3,75 (0,25)	1,26 (0,16)	0,71 (1,5)
Brazil	2,83 (0,43)	2 (1,37)	8,87 (0,15)	3,07 (0,21)	2,95 (0,13)	4,01 (0,16)	1,15 (0,1)	-1,13 (0,87)
Chile	2,73 (0,26)	4,83 (3,01)	9 (0,41)	4,07 (0,16)	3,07 (0,16)	3,96 (0,07)	1,01 (0,08)	-0,12 (1,68)
Colombia	2,75 (0,22)	2,56 (1,63)	8,36 (0,23)	3,52 (0,13)	2,97 (0,14)	3,97 (0,07)	1,02 (0,04)	-1 (0,82)
Costa Rica	2,84 (0,21)	3,78 (1,91)	8,97 (0,28)	4,32 (0,13)	2,99 (0,08)	4,05 (0,1)	0,91 (0,06)	0,33 (1,52)
Dominican Republic	2,85 (0,21)	2,67 (1,57)	8,33 (0,36)	4,13 (0,19)	3,08 (0,16)	3,97 (0,11)	0,82 (0,13)	-0,35 (1,57)
Ecuador	2,87 (0,22)	1,21 (0,92)	8,47 (0,14)	3,83 (0,21)	3,02 (0,16)	3,9 (0,06)	0,94 (0,04)	0,24 (1,03)
Egypt	2,76 (0,1)	2,81 (2,11)	7,83 (0,29)	3,89 (0,22)	3,05 (0,27)	3,87 (0,06)	1,12 (0,13)	-0,13 (1,71)
Fiji	2,42 (0,13)	5,15 (4,48)	8,33 (0,18)	4,71 (0,13)	2,84 (0,23)	3,97 (0,07)	0,9 (0,06)	-0,91 (0,5)
Gabon	2,03 (0,66)	1,9 (3,98)	8,99 (0,12)	4,48 (0,12)	3,29 (0,21)	3,62 (0,19)	1,14 (0,11)	-0,8 (0,53)
Guatemala	2,77 (0,13)	1,59 (0,93)	8,08 (0,14)	3,86 (0,27)	2,7 (0,18)	4,04 (0,05)	0,98 (0,03)	1,01 (1,5)
India	2,78 (0,06)	0,93 (0,9)	6,67 (0,5)	3,27 (0,51)	3,29 (0,17)	3,72 (0,12)	0,76 (0,12)	-1,23 (0)
Iran (Islamic Republic of)	2,58 (0,2)	0,4 (0,59)	8,34 (0,18)	3,67 (0,31)	3,36 (0,17)	3,94 (0,06)	1,05 (0,1)	-1,15 (0,78)
Jordan	2,66 (0,24)	4,25 (5,06)	8,29 (0,12)	4,76 (0,16)	3,19 (0,26)	4,11 (0,03)	1,25 (0,33)	0,99 (1,49)
Mauritius	2,8 (0,21)	1,67 (1,61)	8,55 (0,46)	4,75 (0,11)	3,11 (0,16)	4,02 (0,13)	0,86 (0,09)	0,43 (1,48)
Mexico	2,88 (0,09)	2,12 (0,88)	9,03 (0,1)	3,81 (0,38)	3,01 (0,1)	4,08 (0,02)	1,1 (0,12)	0,49 (1,03)
Morocco	2,86 (0,1)	1,83 (1,47)	7,54 (0,3)	4,13 (0,21)	3,3 (0,12)	3,89 (0,05)	0,9 (0,06)	-1,26 (0,4)
Panama	2,35 (0,4)	4,95 (4,94)	8,95 (0,35)	4,82 (0,2)	3,1 (0,46)	4,22 (0,04)	1,06 (0,06)	2,31 (0)
Paraguay	2,8 (0,12)	0,92 (0,67)	8,34 (0,16)	4,28 (0,36)	2,96 (0,13)	3,78 (0,06)	0,9 (0,09)	-0,09 (1,01)
Philippines	3,14 (0,09)	1,38 (0,74)	7,63 (0,24)	4,04 (0,32)	3,06 (0,16)	3,87 (0,16)	0,85 (0,1)	-0,46 (0,63)
Saudi Arabia	2,23 (0,25)	1,64 (2,5)	9,86 (0,17)	4,3 (0,15)	3,06 (0,14)	3,77 (0,18)	1,56 (0,46)	1,61 (0,61)
South Africa	2,86 (0,22)	0,91 (1,18)	8,6 (0,11)	3,89 (0,15)	2,91 (0,21)	4,05 (0,13)	1,09 (0,08)	-1,34 (0,42)
Sri Lanka	2,75 (0,13)	1 (0,46)	7,56 (0,47)	4,19 (0,19)	3,22 (0,11)	3,95 (0,1)	0,9 (0,09)	-0,5 (0,78)
Swaziland	3,34 (0,27)	2,66 (2,71)	7,8 (0,33)	4,85 (0,26)	2,87 (0,28)	3,77 (0,13)	0,83 (0,17)	-0,84 (0,51)
Turkey	2,93 (0,13)	0,91 (0,91)	8,81 (0,33)	3,72 (0,29)	3,13 (0,22)	3,94 (0,06)	1,02 (0,06)	-0,78 (0,63)

The table shows the means over the study period and the associated standard deviation in parentheses.

To avoid any lack of robustness or misleading results in our analysis, we performed unit root tests. As each test has its limitations, we conducted four tests and compared the results: the Im-Pesaran-Shin (IPS) test, the Levin-Lin-Chu (LLC) test, and the Phillips-Perron and Fisher Dickey-Fuller tests.⁵

These tests, known as first-generation panel unit root tests, assume cross-sectional independence of the panel data, which we confirmed with tests proposed by Pesaran (2021, 2015, 2004). The Pesaran (2004) test allows us to assess cross-sectional independence (under the null hypothesis). Meanwhile, the Pesaran (2015) test evaluates weak cross-sectional dependence (under the null hypothesis) against strong cross-sectional dependence (under the alternative hypothesis). The cross-dependence (CD) statistic yielded a value of 1.39 with a p-value of 0.166, which leads us to not reject the null hypothesis of cross-sectional independence.⁶ The results of the first-generation unit root tests are thus valid and interpretable.

Nonetheless, correlations resulting from common shocks with heterogeneous impacts across countries, such as the oil price shock in the 1970s or the 2007 global financial crisis, can lead to cross-sectional dependence (CSD) in panel data (Lau

⁵It should be noted that each test has different hypotheses and is subject to various data restrictions. For a deeper understanding of their assumptions, limitations, and constraints, see Maddala and Wu (1999); Hurlin and Mignon (2005).

⁶To avoid bias, we estimate the fixed-effect model, as suggested by Hausman (1978), without including lagged dependent variables. We then re-run the estimation and tests with the lagged dependent variable among the control variables and obtain consistent results.

et al., 2019; Atasoy, 2017). The presence of CSD can cause biased and inconsistent estimates, necessitating alternative estimation methods like second-generation panel unit root tests (Appiah et al., 2023; Lau et al., 2019). Ignoring this residual correlation can severely impact estimator efficiency and test validity due to unaddressed dependence among residuals (Apergis et al., 2017; Apergis, 2016).

To verify robustness, we also conducted a second-generation unit root test, specifically the Pesaran (2007) test, which assumes weak cross-sectional dependence in our sample (presented in Table 4.A3 in the appendix). The results align with those from the first-generation unit root tests. The various test outcomes for each variable are recorded in Panel A of Table 4.5. These findings suggest that variables such as FDI and Investment are stationary, while the others are not.

We therefore performed a first-difference transformation on these variables and verified their stationarity in first differences. The tests confirm that variables including Industrialisation, GDP per capita, capital account liberalisation, service, total factor productivity, and trade are stationary in first difference at the 5% level, indicating they are integrated of order 1. The results are detailed in Panel B of Table 4.5.

Co-integration Test

To avoid spurious regression due to the presence of integrated variables of order 1 in the model, Lo and Ramde (2019) emphasize the importance of investigating the presence or absence of a long-term relationship between the variables. According to these authors, when there is a shared long-term dynamic between variables, the VAR model should be estimated with an error correction mechanism. Consequently, it becomes necessary to apply a VAR model with error correction.

To examine the long-term relationship between the variables, we utilize the Kao (1999) cointegration test, as recommended by Lo and Ramde (2019). The results indicate that, at the 5% significance level, we fail to reject the null hypothesis of no cointegration (Table 4.6), which permits us to estimate the VAR model without incorporating an error correction mechanism.

As these are first-generation cointegration tests, which assume cross-sectional independence in panel data, we conducted a second-generation cointegration test for robustness. Specifically, we performed the Westerlund (2007) test with a bootstrap

Table 4.5: Unit root tests

Variable		LLC	IPS	ADF		PP	
				P Stat.	Pm Stat.	P Stat.	Pm Stat.
Panel A: Variable in level							
FDI	Stat.	-6.862	-6.349	-4.963	5.658	-8.824	14.414
	P-Val.	3.40E-12	1.09E-10	3.47E-07	7.65E-09	5.50E-19	0.00E+00
Capital	Stat.	-1.173		-0.761	0.305	-0.241	-0.472
	P-Val.	0.12		0.22	0.38	0.40	0.68
Productivity	Stat.	-1.567	-0.890	-1.377	4.093	-1.369	2.783
	P-Val.	0.06	0.19	0.08	0.00	0.09	0.00
Industrialization (log)	Stat.	0.361	1.941	2.436	-1.780	1.800	-0.560
	P-Val.	0.641	0.974	0.993	0.962	0.964	0.712
GDP per capita (log)	Stat.	2.172	6.116	5.592	-0.670	6.405	-2.051
	P-Val.	0.985	1.000	1.000	0.749	1.000	0.980
Trade (log)	Stat.	-3.112	-2.030	-2.166	1.482	-0.972	-0.012
	P-Val.	0.001	0.021	0.015	0.069	0.166	0.505
Service (log)	Stat.	-2.799	-1.098	-0.617	0.660	-1.064	1.374
	P-Val.	0.003	0.136	0.269	0.255	0.144	0.085
Investment (log)	Stat.	-5.371	-5.364	-5.979	7.464	-4.715	5.148
	P-Val.	3.92E-08	4.07E-08	1.12E-09	4.19E-14	1.21E-06	1.32E-07
Panel B: Variable in first difference							
Capital	Stat.	-12.600		-16.913	35.293	-25.286	72.072
	P-Val.	1.05E-36		1.79E-64	0.00E+00	2.27E-141	0.00E+00
Productivity	Stat.	-13.760	-16.620	-17.624	38.808	-22.553	62.049
	P-Val.	2.22E-43	2.49E-62	8.10E-70	0.00E+00	6.31E-113	0.00E+00
Industrialization (log)	Stat.	-13.377	-16.379	-17.347	38.211	-26.102	79.099
	P-Val.	4.10E-41	1.36E-60	1.04E-67	0.00E+00	1.72E-150	0.00E+00
GDP per capita (log)	Stat.	-12.104	-14.430	-15.398	31.254	-19.920	50.726
	P-Val.	5.03E-34	1.68E-47	8.38E-54	0.00E+00	1.37E-88	0.00E+00
Trade (log)	Stat.	-13.990	-17.175	-18.190	40.452	-26.032	75.929
	P-Val.	8.91E-45	2.05E-66	3.08E-74	0.00E+00	1.07E-149	0.00E+00
Service (log)	Stat.	-14.934	-17.392	-18.438	40.988	-27.149	83.576
	P-Val.	9.95E-51	4.75E-68	3.23E-76	0.00E+00	1.29E-162	0.00E+00

of 100 replications to account for any cross-sectional dependence in the panel. The second-generation test confirmed the results of the first-generation cointegration tests (see Table 4.A4 in the appendix).

Specification of the Panel VAR

The specification of the PVAR model involves first determining the optimal lag, then ensuring the overall stability of the model, and finally establishing the order of integration of the variables.

Determination of the Optimal Lag

Similar to the standard VAR model, estimating a PVAR requires determining an optimal lag to properly specify the model. This optimal lag, also known as the order of the PVAR (denoted as p in Equation 4.1), is crucial. Andrews and Lu (2001) introduce the *MMSC* information criteria, which are tailored to the GMM model. These *MMSC* criteria are calculated based on the J statistic for over-identification

Table 4.6: KAO cointegration tests

		DF*	DF t*	ADF	DF rho	DF t
GDP per capita (log)	Stat.	0,198	-0,222	-0,677	-0,284	-0,573
	P-Val.	0,422	0,412	0,249	0,388	0,283
Capital	Stat.	0,269	0,098	-0,172	0,038	-0,075
	P-Val.	0,394	0,461	0,432	0,485	0,470
Service (log)	Stat.	0,192	-0,137	-0,304	-0,303	-0,498
	P-Val.	0,424	0,445	0,381	0,381	0,309
Trade (log)	Stat.	0,688	0,583	0,004	0,181	0,177
	P-Val.	0,246	0,280	0,498	0,428	0,430
Productivity	Stat.	0,873	0,721	0,468	0,343	0,283
	P-Val.	0,191	0,236	0,320	0,366	0,389
All	Stat.	-0,141	-0,261	-0,545	-0,496	-0,508
	P-Val.	0,444	0,397	0,293	0,310	0,306

restrictions proposed by [Hansen \(1982\)](#). They are analogous to the information criteria typically used in the Method of Moments, namely Akaike (*AIC*), Schwartz (*BIC*), and Hannan-Quinn (*HQIC*) criteria, all of which should be minimized. Specific conditions apply to these criteria⁷. If these conditions are not satisfied, [Abrigo and Love \(2016\)](#) recommend using the Coefficient of Determination (*CD*) as an alternative criterion. The *CD* reflects the proportion of variation explained by the PVAR model.

Table 4.7 presents the values of the aforementioned criteria. By minimizing the *MMSC* information criteria, we find that the optimal order to retain is 1 lag.

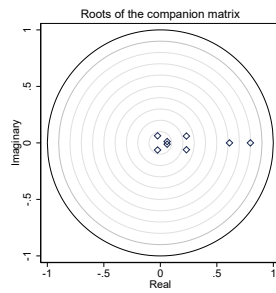
Table 4.7: Choice of the optimal lag

Lag	CD	J	J pvalue	BIC	AIC	QIC
1	0.980	262.330	0.379	-1483.314	-249.670	-720.557
2	0.991	191.505	.4965143	-1117.729	-192.495	-545.661
3	0.994	98.063	0.977	-774.759	-157.937	-393.381
4	0.996	55.787	0.758	-380.625	-72.213	-189.935
5	0.990					

Stability test

The stability of a VAR model is crucial and is a prerequisite for VAR estimation. It implies that the PVAR is invertible and has an infinite order moving average vector representation ([Abrigo and Love, 2016](#)) allowing us to interpret the estimated im-

⁷See [Andrews and Lu \(2001\)](#) and [Hansen \(1982\)](#) for further information.



Real Eigenvalue	Imaginary Eigenvalue	Modulus
0.797	0.000	0.797
0.612	0.000	0.612
0.231	-0.060	0.239
0.231	0.060	0.239
-0.025	-0.063	0.067
-0.025	0.063	0.067
0.060	-0.012	0.061
0.060	0.012	0.061

Figure 4.1 & Table 4.8: Model stability

pulse responses and the prediction error variance decompositions. The VAR model is stable if all *Modulus* are strictly less than 1. In our study, the stability condition is verified and confirmed by Table 8 and Figure 1 where all the values of *Modulus* are in the circle.

Order of PVAR, Causality Test and Centrality of Variables

The order in which variables are introduced into the PVAR model implies that variables appearing earlier in the sequence impact subsequent variables both immediately and with a delay, while variables introduced later only influence preceding variables with a delay. Thus, variables appearing earlier in the system are considered more endogenous (or most affected) and those appearing later are deemed more exogenous (or most causal).

To specify the ordering in our VAR model, we used Granger causality tests along with an assessment of variable centrality based on network and graph theory principles.

Since a variable may cause multiple other variables (and in turn be influenced by others), it is essential to identify the variables that are most significantly causal within our model. We apply the Granger causality test to perform this sorting. The results are presented in Table 4.9. In the table, lagged variables are shown in rows, and contemporaneous variables are shown in columns. As these relationships may be complex to interpret, they are summarized in a causal matrix (Table 4.10).

This matrix allows for an analysis of the relative importance of each variable within the network (Table 4.11). A variable's importance, or "centrality," is measured through centrality indicators. Given our use of a directional network, we

Table 4.9: Causality test

Exched variable	Equation variable							
	Industrialization	FDI	Capital	Investment	GDP per capita	Trade	Service	Productivity
Industrialization		0.036	0.299	1.551	1.215	1.496	0.043	1.207
FDI	6.208**		0.074	6.023**	2.599	0.913	0.035	1.035
Capital	1.970	1.154		6.144**	9.814***	0.197	0.446	3.341*
Investment	0.000	0.029	0.029		0.081	13.277***	0.426	0.782
GDP per capita	0.372	4.748**	1.099	3.001*		0.449	1.258	0.214
Trade	0.011	2.637	3.604*	4.613**	11.341***		18.807***	0.047
Service	3.235*	14.317***	0.519	0.037	8.707***	1.090		23.941***
Productivity	0.986	7.875***	3.175*	0.000	0.187	1.335	1.955	
ALL	24.735***	45.328***	14.923**	38.695***	80.374***	19.241***	31.307***	39.234***

*** p<0.01, ** p<0.05, * p<0.1

Table 4.10: Unweighted matrix

	Industrialization	FDI	Capital	Investment	GDP per capita	Trade	Service	Productivity
Industrialization								
FDI	1			1				
Capital				1	1			1
Investment						1		
GDP per capita		1		1				
Trade			1	1	1		1	
Service	1	1			1			1
Productivity		1	1					

A cell of the matrix takes 1 if the row variable (with a lag of one period) significantly causes the column variable in the Granger sense.

distinguish between outgoing, incoming, and combined degree centralities for each node. In this context, authorities are nodes with numerous incoming connections; a strong authority suggests a variable that is more influenced by others, while a weak authority indicates a more exogenous (or causal) variable. For clarity, note that hubs are nodes with numerous outbound connections to authorities, while eigenvector centrality measures a node's connectivity with other well-connected nodes in the graph.

We then constructed this matrix into a network based on network and graph theory, incorporating the causal directions defined by the Granger causality relationships (Figure 4.2). Finally, we identified the most central variables by their authority level within the network, ranking them from most endogenous to most exogenous.

Our chosen specification follows this order: *Investment* $\rightarrow$ *GDP per capita* $\rightarrow$ *FDI* $\rightarrow$ *Productivity* $\rightarrow$ *Industrialization* $\rightarrow$ *Capital* $\rightarrow$ *Service* $\rightarrow$ *Trade*.

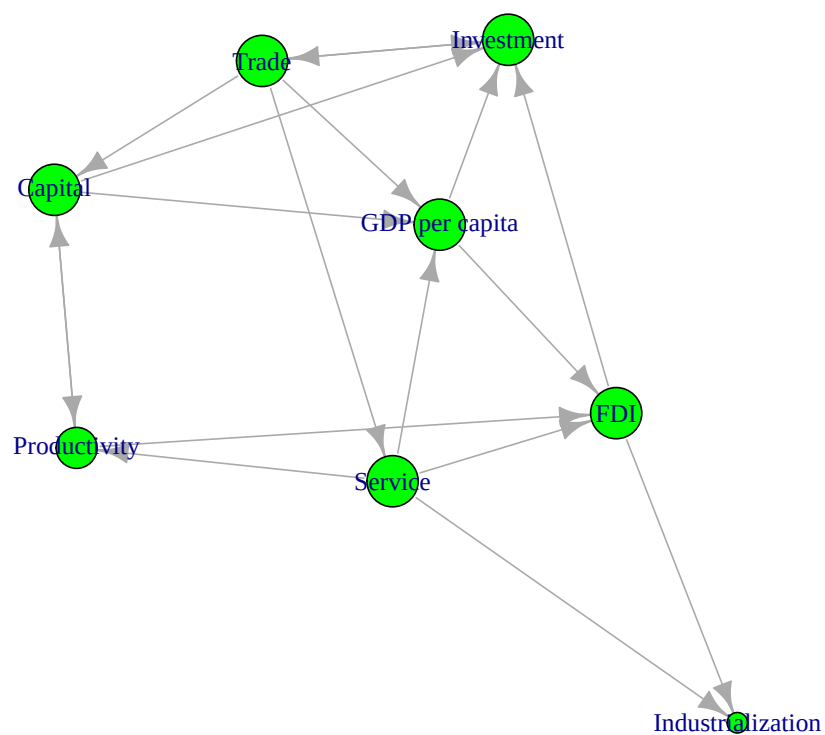


Figure 4.2: Centrality of variables

Table 4.11: Centrality of variables

	Measures of Centrality			Authority	Hub	Eigenvectors
	Outgoing degree	Incoming degree	Both degree			
Industrialization	0	2	2	0.500	0.000	0.347
FDI	2	3	5	0.648	0.550	0.820
Capital	3	2	5	0.453	0.946	0.942
Investment	1	4	5	1.000	0.000	1.000
GDP per capita	2	3	5	0.950	0.605	0.969
Trade	4	1	5	0.000	1.000	1.000
Service	4	1	5	0.322	1.000	0.820
Productivity	2	2	4	0.628	0.404	0.745

4.4 Results

4.4.1 Baseline results

Output interpretation

We estimate the PVAR model using a GMM approach. However, as our model is sensitive to endogeneity, we have used upstream lags of one or two periods on variables introduced as instruments. The approach and results are reported in Table 4.A6 of Appendix B. Hansen's J statistic and the associated probability validate the instruments used.

The results of the industrial sector's responses to macroeconomic shocks are shown in Figure 4.3. Sub-figure 4.3a shows the impulse response functions (IRFs) and sub-figure 4.3b the cumulative responses (cumulative IRFs).

Impulse response functions (IRFs) describe the response of one variable to the shock of another variable in the system, all other shocks being maintained at zero. We orthogonalize the impulse responses so that we can isolate the shock of one variable on the other variables. The coefficients associated with the impulse response functions are estimated with standard deviations. We generate the interval of IRF trusts by Monte Carlo simulations with 1000 repetitions. In addition, we use cumulative responses to analyze the persistence of the shock over time. Because of the temporal dimension of our study, we study the dynamics of responses to different shocks over a period of ten years.

In the PVAR model, an impulse represents a variation of one standard deviation in the variable X , whether differentiated or presented in levels (Grossmann et al., 2014). The IRFs (Sub-figure 4.3a) show the response to the shock in each time period. In this study, the effect of shocks is analyzed over a period from $t = 0$

(immediate response to shock) to $t = 10$ years (long-term response to shock). Cumulative IRFs (Sub-figure 4.3b) represent the sum of these effects. For example, a cumulative effect in $t = 10$ represents the sum of the effects of the periods from $t = 0$ to $t = 10$. hence, while IRFs enable us to analyze the dynamics of the effect, cumulative IRFs enable us to understand the persistence of the shock's effect.

Analysis of the effect of shocks in external determinants

Graphical analysis of the results (Sub-figure 4.3a) shows that FDI shocks positively affect industrialization for all periods from $t = 0$ to $t = 10$. This effect is statistically significant for $t = 0$ and $t = 1$ (see results in appendix B). The analysis of cumulative IRFs (Sub-figure 4.3b) also shows that this positive effect decreases over time. This result is stable, significant and persistent over time (see associated coefficients in the appendix B).

No effect appears in the short or long term in the trade variable. This suggests that a shock to trade would not affect a country's industrialization levels. On the other hand, a negative effect seems to emerge for the capital account variable, implying that a shock to capital account would have a negative effect on industrialization levels in emerging countries. However, this effect is insignificant over both short and long periods.

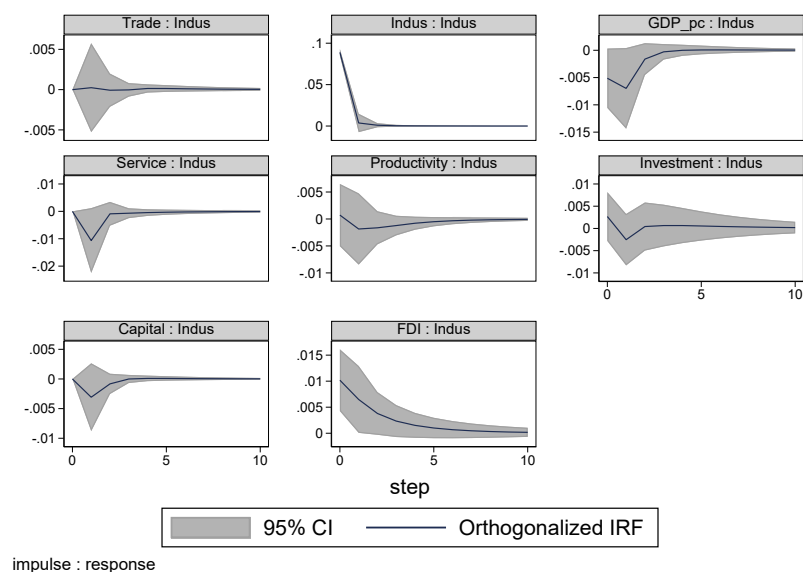
Analysis of the effect of shocks in internal determinants

A shock in the industrial sector has a very significant instantaneous contemporary effect for the sector, suggesting a dynamic knock-on effect. This effect is strong and significant, with a very narrow confidence interval around the coefficient. The positive effect quickly subsides for the other short-term periods, but its cumulative effect remains positive and persistent over the long term, suggesting a stable positive effect for the industrial sector.

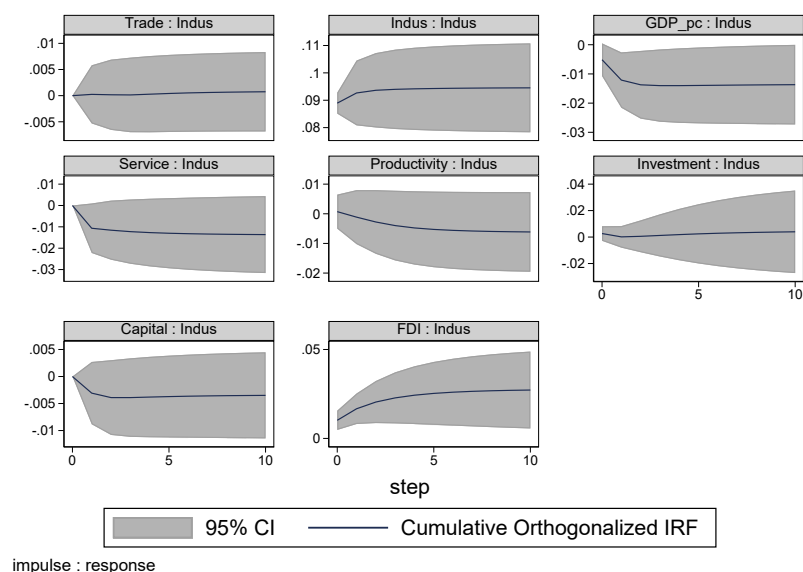
We also see that a shock to GDP per capita negatively affects industrialization. Although this shock is not statistically visible in short-term periods, the cumulative effect is significant, stable, and persistent until $t = 9$.

The effect of a shock in services or productivity seems to be negative in the short term and persistent at industrialization levels. However, these effects are insignificant in our sample. Finally, we can see that an impact on investment could have an effect on industrialization, but that this effect is inconsistent, insignificant

and disappears completely in the long term.



(a) IRF



(b) Cumulative IRF

Figure 4.3: Response of industrialization to macroeconomic shocks

Note: Indus = *Industrialization*

Variances decomposition

The decompositions of the variance show the percentages of the cumulative variation of one variable explained by the shock of another variable. They show the magnitude of a shock in the total variation or the total effect. Table 4.12 reports the results of the 10-year variance decompositions. It shows the share of the total variation or the total effect of a shock on industrialization explained by the shock of

each variable. The table shows that the variations of the Industrialization variable are explained by 1.7% of the FDI shock, 1.1% by the services sector shock and 0.8% by the GDP per capita.

In sum, the table shows that the development of the service sector and FDI shocks account for a large share of changes in the industrial sector. It is shown that if these shocks affect the industrial sector, it remains fairly rigid in the face of other shocks, except shocks internal to the industrial sector itself.

Table 4.12: Variance decompositions

	Industrialization
Investment	0,002
GDP pc	0,008
FDI	0,017
Productivity	0,001
Indus	0,869
Capital	0,001
Service	0,011
Trade	0,000

4.4.2 Searching for structural breaks

The results presented above are obtained following an analysis over the entire period (1980 to 2019). We will now examine whether our study period is subject to structural breaks. A structural break is a sharp break in economic dynamics over a given period. A sudden change of sign in the dynamics of variables can lead to a change in effects. Such breaks, if undetected, or if poorly taken into account in the analysis, can lead to biases in the interpretation of results.

We will therefore investigate whether our period shows any breaks, and if so, we will estimate the years of these phenomena (Ditzen et al., 2021; Bai and Perron, 2003, 1998). This will enable us to carry out sub-period analyses.

Table 4.13 shows the results of the break-finding test. The test of Bai and Perron (2003, 1998) verifies, by iterating, the null hypothesis of 0 against 1 break, then 1 against 2 breaks, and so on. It shows the presence of 2 break periods in our sample (it cannot reject the null hypothesis when there are three breaks). Next, we examine the estimated break dates, and the associated confidence intervals (Ditzen et al., 2021). The first break is estimated at the 10th period, corresponding to 1989, while

the second is estimated at the 25th year, corresponding to 2004. The confidence intervals for both breakpoints are only one year, suggesting that the estimates are accurate.

On a global scale, 1989 saw the fall of the Berlin Wall and the end of the Cold War between the United States and the Soviet Union. The Eastern bloc's transition to a market economy and the end of bipolarity profoundly altered global trade dynamics. A number of other regional crises have also had the effect of disrupting the dynamics of emerging countries. Examples include the 1989 invasion of Panama by the United States, the sharp fluctuations in commodity prices that affected food exporting countries, and the political instability and hyperinflation of certain Latin American countries.

The same applies to 2004, the year in which the European Union enlarged to include ten new members, mainly Eastern European countries. This rapid expansion of the single market and the resulting institutional upheaval could explain a change in trade flows between the economic powers of the EU and emerging countries. The same year also saw a number of political and economic instabilities in the countries in our sample. These include economic crises in Latin America, the outbreak of war in Iraq in 2003, and major reforms in India, Mexico and Brazil aimed at attracting foreign direct investment and promoting economic recovery.

To take account of these break-off years in our analysis, we have re-analyzed our results for three sub-periods: 2005-2019, 1990-2003 and 1980-1988. Where the period allows, we perform all the pre-tests related to PVAR method. We estimate impulse responses over a 6-year period. We present the results of estimating cumulative orthogonal impulse responses in Figure 4.4 for the post-2004 sub-period, in Figure 4.5 for the 1990-2003 sub-period and in Figure 4.6 for the 1980-1988 sub-period. As a precaution, we avoid interpreting the results prior to 2004, as the time length of the sub-periods concerned were too short to provide effective tests and therefore reliable results. However, a general analysis of the different results shows that, depending on the sub-period, the effects of the different variables on industrialization are different (change of sign). These results underline the importance of understanding the underlying mechanisms, which evolve over time and in line with global economic transformations.

External determinants

For FDI, sub-period analysis shows that the results found in the global model come mainly from the period after 2004. Prior to that, results were inconsistent. It should be remembered, however, that these 2 periods must be analyzed with caution, given the limited reliability of the data.

The sub-period results also show a zero effect of the level of openness (capital account) on industrialization for the period 1980 to 1989, as well as for the period after 2004. However, we note a strong, significant and persistent negative effect in the second period, which could explain the trend of the curve in the overall effect.

The trade is inconsistent between periods and remains insignificant.

Internal determinants

Overall, the sub-period analysis for GDP shows an instantaneous effect in short periods (sometimes slightly positive, but overall negative). In the medium term, however, we note a return to a zero effect. Although counter-intuitive, these results suggest, in the short term, that a positive GDP per capita shock will have a negative effect on industrialization.

Investment will tend to behave similarly, with an instantaneous positive and significant effect, followed in the short term by a negative effect, and then a return to the zero effect.

The effect of a shock in services, on the other hand, is highly inconsistent between periods, as well as within the same period, making any interpretation as it stands rather hazardous. We will discuss this effect in greater detail in the next section.

For productivity, the effect is globally null and insignificant, except in the post-2004 period in which it is negative, significant and persistent.

The effect of previous industrialization shock on industrialization is strong, stable, persistent, and consistent between periods, as in the basic results of our model. We have a significant positive shock in the short term, whose cumulative effects remain persistent over time.

4.4.3 Another measure of industrial development: employment

To ensure the robustness of our results, we replace the industrialization variable with employment in the manufacturing sector (Employment in industry as a % of

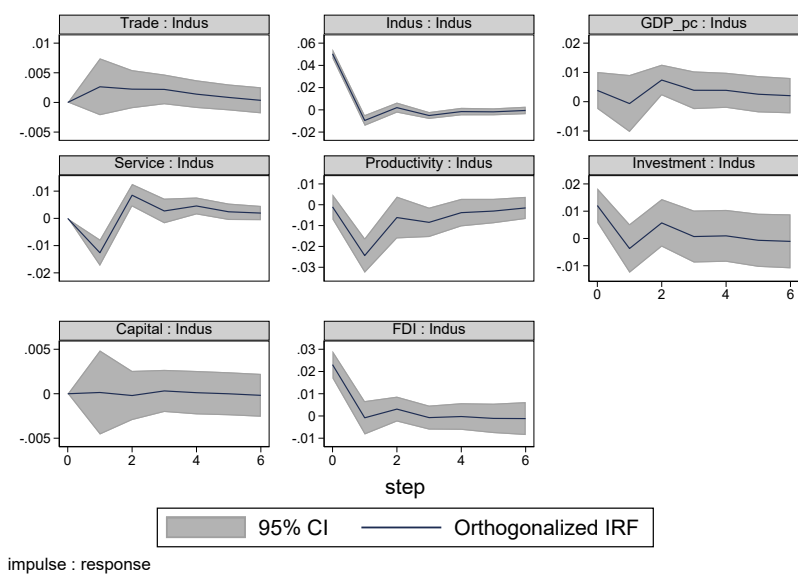
Table 4.13: Structural breaks test

Test Statistic		Bai & Perron Critical Values		
		1% Critical Value	5% Critical Value	10% Critical Value
F(1 0)	30.95	4.08	3.35	2.99
F(2 1)	7.49	4.32	3.69	3.34
F(3 2)	2.26	4.51	3.84	3.53
F(4 3)	0.91	4.59	3.96	3.68
F(5 4)	0.32	4.70	4.07	3.77
Detected number of breaks:		2	2	2
Break	Index	Date	[95% Conf. Interval]	
1	10	1989	1988	1990
2	25	2004	2003	2005

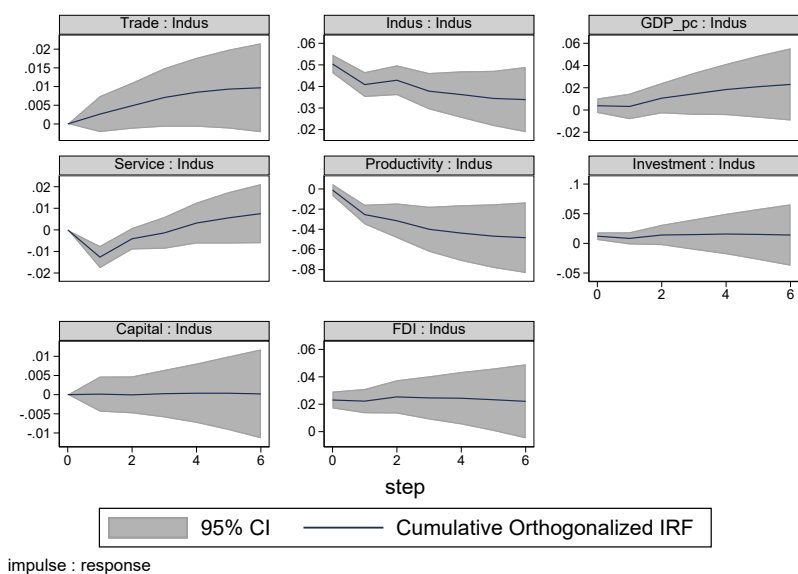
total employment; modeled by ILO estimate) (see [Gui-Diby and Renard \(2015\)](#); [Kang and Lee \(2011\)](#)). We focus on the post-2004 period due to the limited availability and quality of data for earlier periods. The results are presented in Figure 4.7. We observe that a positive shock in trade could have short-term positive effects, although these effects dissipate over time. The effect of FDI, however, becomes insignificant and may change sign, with a less marked impact overall. This could suggest that firms are channeling the positive FDI shock toward physical capital at the expense of human capital. The other results remain stable, confirming the findings of the main analysis.

4.4.4 Decomposition of Trade in Manufacturing

We also examine whether the effect of trade on industrialization is consistent when considering the import and export sides separately by decomposing trade into imports and exports, as these two variables may have differentiated effects on industrialization ([Samouel and Aram, 2016](#)). For simplicity, we isolated the components of imports and exports related exclusively to the manufacturing sector. Similar to the previous analysis, we limit this robustness check to the post-2004 period due to data availability and quality. The results are presented in Figure 4.8. The effects are not significant in our sample; however, if confirmed by future studies, they would suggest a slightly positive short-term effect of export shocks on



(a) IRF

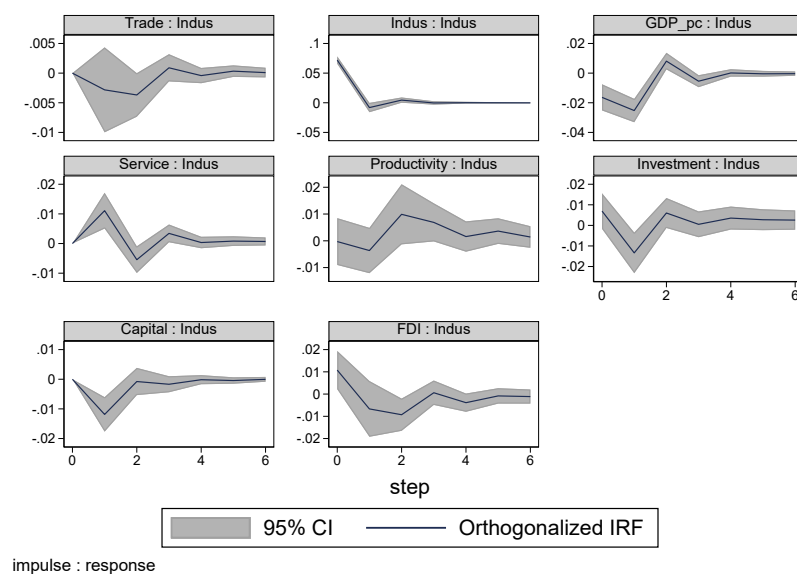


(b) Cumulative IRF

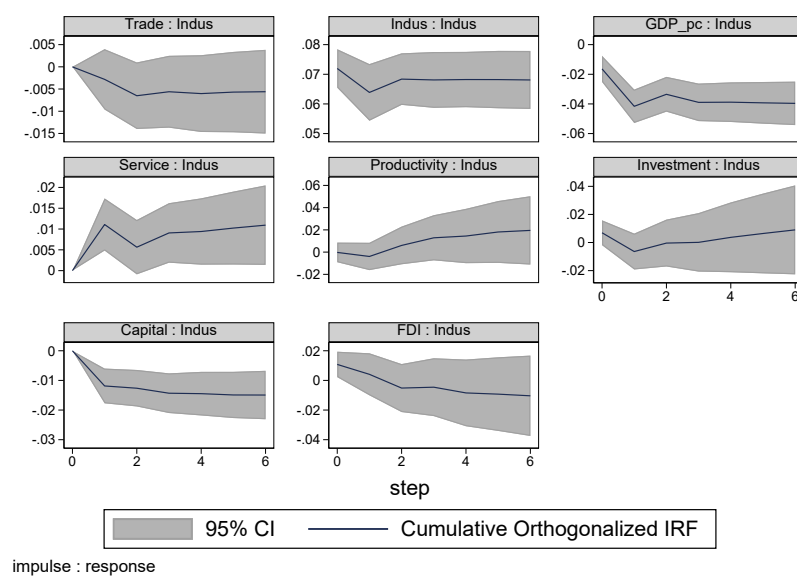
Figure 4.4: Response of industrialization to macroeconomic shocks: after 2004

Note: Indus = *Industrialization*

industrialization, coupled with a slightly negative effect of import shocks. Finally, it is noteworthy that these effects would dissipate over time.



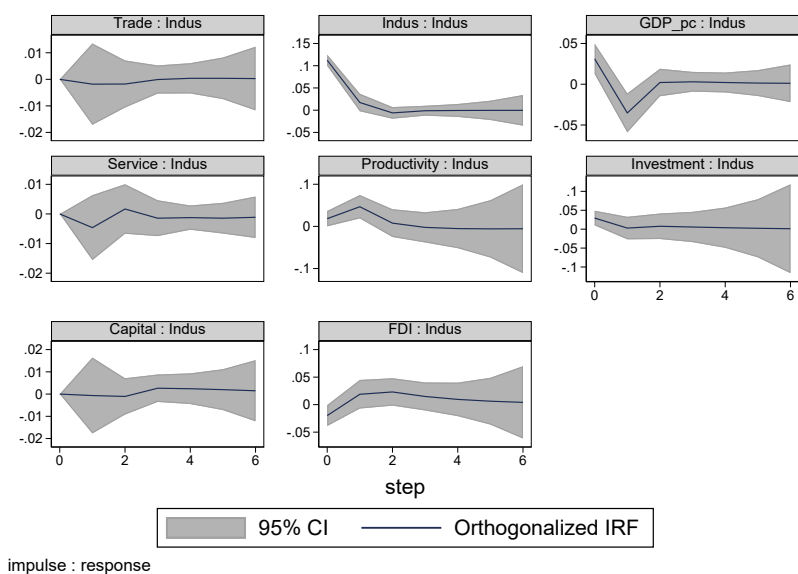
(a) IRF



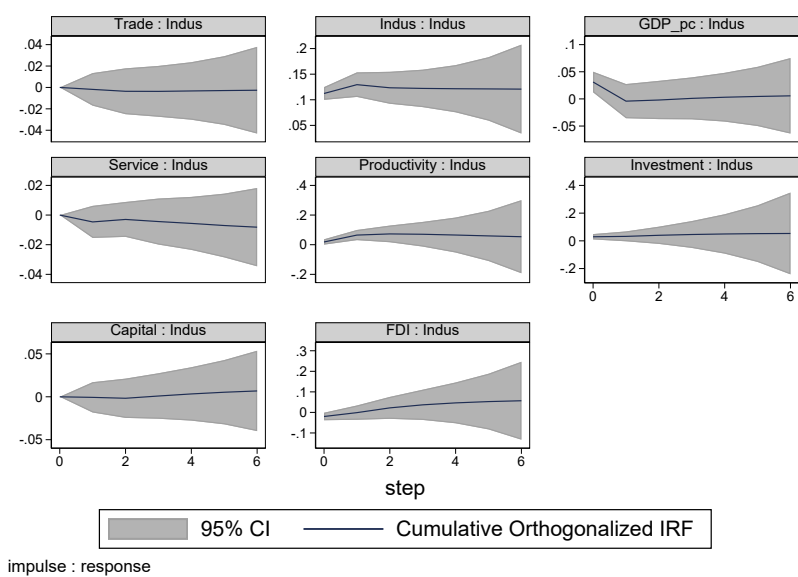
(b) Cumulative IRF

Figure 4.5: Response of industrialization to macroeconomic shocks: 1990-2003

Note: Indus = *Industrialization*



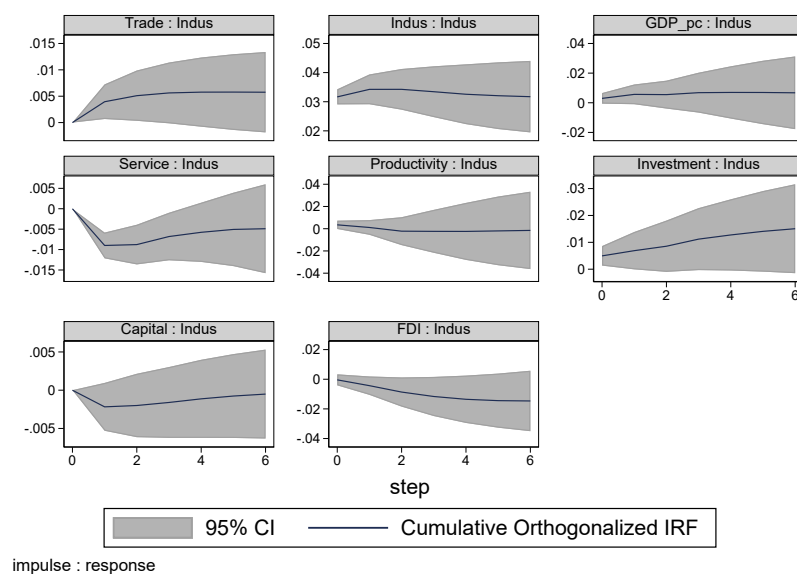
(a) IRF



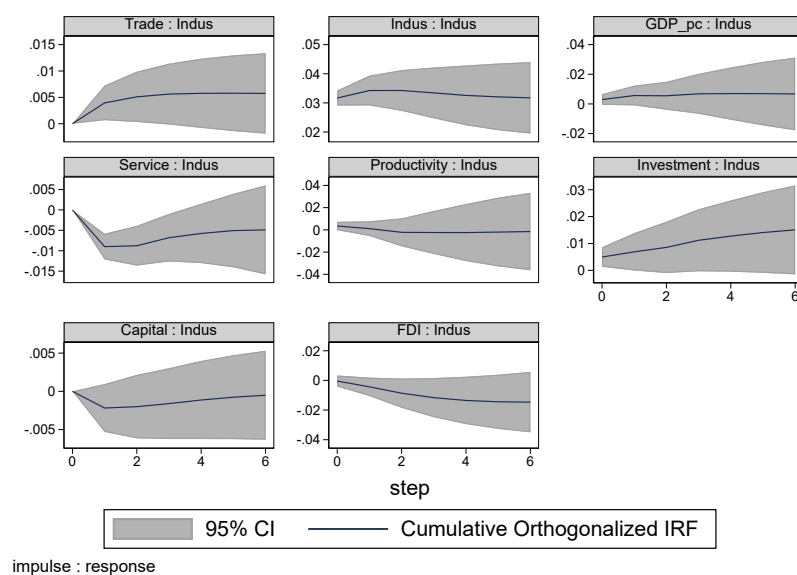
(b) Cumulative IRF

Figure 4.6: Response of industrialization to macroeconomic shocks: before 1990

Note: Indus = *Industrialization*

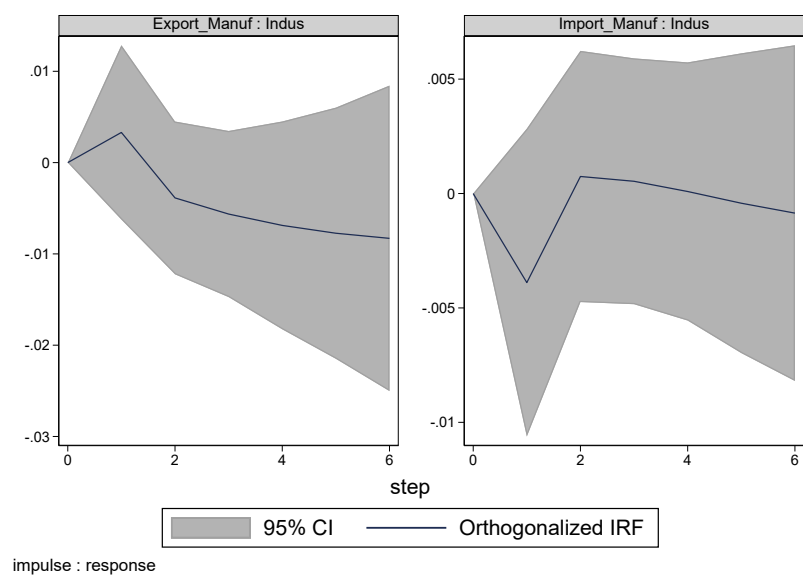


(a) IRF with industrial employment

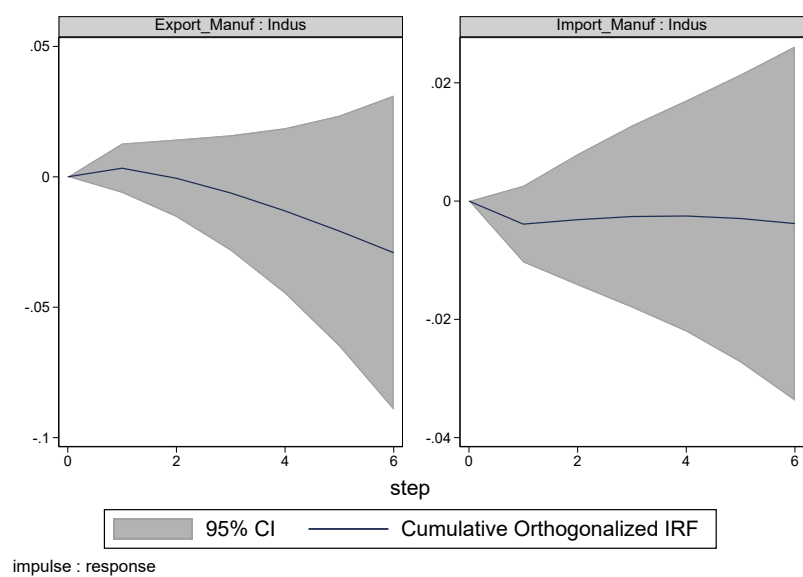


(b) Cumulative IRF with industrial employment

Figure 4.7: Estimation using employment: After 2004Note: Indus = *Industrialization*



(a) IRF



(b) Cumulative IRF

Figure 4.8: Decomposition of Trade in Manufacturing: After 2004

Note: Indus = *Industrialization*

4.5 Discussion

External determinants

Our study of shocks to the internal and external determinants of industrialization in emerging countries shows that positive shocks to FDI have a short-term effect, and this effect remains persistent over time. An in-depth analysis of our sample across sub-periods indicates that this effect is stable only for the most recent period (post-2004). This suggests that profound changes in the global economic structure since 2004 (e.g., increased free trade, stronger global value chains) have had a lasting impact on emerging economies. It is worth noting that, at the beginning of this period, certain countries (e.g., India, Mexico, Brazil) introduced policies to attract FDI. The instability of results over the period 1990-2003 could be attributed to shifts in the direction of foreign direct investment. The re-opening of Eastern European countries to the free market may have temporarily favored investment in these economies rather than in the countries in our sample.

Moreover, a shock to the capital account does not appear to have any significant effect on industrialization. Aside from a minor effect at the beginning of the 1990s, this result is confirmed across all our analyses. This finding suggests that the level of openness of an economy does not directly impact industrialization in emerging countries, except potentially during the 1990-2004 period. A subgroup analysis could be beneficial here to assess whether this negative effect originated from a specific group of countries, or if shifts in global financial flows over this period, combined with a shock in openness, negatively impacted industrialization in emerging economies.

Regarding trade shocks, our study finds that they do not appear to directly influence industrialization. However, since imports and exports have opposing effects ([Samouel and Aram, 2016](#)), it is likely that this impact cannot be captured directly here. A more detailed analysis of trade shock dynamics across sub-periods, distinguishing between the effects of imports and exports, seems crucial. This would enable a more accurate assessment and forecast of how changes in liberalization policies may impact the industrial density in emerging countries. Unfortunately, the limited scope of our current dataset precludes us from conducting such analyses.

Internal determinants

An analysis of the three periods reveals that the effect of a positive shock to GDP

Table 4.14: Summary of the effects on industrialization

Shock Variables	Base result	After 2004	1990-2003	Before 1989
<i>Non cumulative effect</i>				
Productivity		-		+
Industrialization	+	+/-	+	+
Service		-/+	+	
Capital			-	
Trade				
Investment		+		+
FDI	-	+	+	-
GDP per Capita			-	+
<i>Cumulative effect</i>				
Productivity		-		+
Industrialization	+	+	+	+
Service		-	+	
Capital			-	
Trade				
Investment		+		+
FDI	-	+	+	-
GDP per Capita	-		-	+

does not necessarily translate into a positive impact on industrialization. Indeed, the effect is at best inconsistent, if not insignificant. Similarly, shocks in the services sector show irregular and contradictory behavior across periods, as well as within these same periods for emerging countries. As [Clark \(1957\)](#) emphasizes the U-shaped relationship between development and industrialization, we suggest that further sub-group analysis—classifying countries based on levels of development, geographical positioning, and/or connections with developed economies—would be beneficial. Such an analysis would enable us to assess whether these characteristics can modify the observed effects or explain the heterogeneity reported (particularly in relation to services shocks).

In our study, investment shocks do not appear to impact industrialization significantly. However, the investment variable here is not specifically linked to manufacturing investment. Overall, infrastructure investment in a country (e.g., technical training, roads, ports) facilitates trade and indirectly attracts investment in the

manufacturing sector. As our data do not allow us to distinguish between these two effects (manufacturing investment versus infrastructure or non-manufacturing investment), this lack of an overall effect should be interpreted with caution.

Finally, we note a significant and persistent effect of industrialization on itself across all our analyses, suggesting a strong short-term dynamic that persists over time.

4.6 Conclusion

Emerging countries have become the driving force behind economic globalization, underscoring their crucial role in international trade and the global production chain ([Organisation for Economic Co-operation and Development, 2009](#)). It is therefore essential to understand how internal and external economic shocks influence the industrialization of these nations.

Globalization has profoundly transformed the worldwide division of labor, with emerging countries playing a central role in global production. Their integration into production and trade networks has created economic interdependencies, meaning that changes in their industrialization will have repercussions on the global economy, and vice versa.

Our study reveals that only the effect of a positive FDI shock seems to be a significant determining factor in the industrialization of emerging countries. Global macroeconomic shocks or public policies favoring FDI would thus contribute directly to industrial development.

The increased interdependence of these countries, through trade and investment, means that economic shocks affecting them can quickly spread across borders via slowdowns in industrial activity. This, in turn, will affect international trade, emphasizing the importance of economic stability in emerging countries for sustaining global economic growth.

Nonetheless, despite the growing interconnectedness of emerging countries, our findings suggest that the impact of economic shocks on industrialization through trade, investment, and shifts in the service sector remains less predictable. The effect of an economic shock on GDP through these variables tends to vary across different periods. This could suggest a “smooth” adjustment process that is chal-

lenging to capture in shock studies, possibly linked to the aggregate structure of these variables. Future research incorporating a disaggregated analysis of trade, investment, and the service sector, using sector or product-level data, could provide a more nuanced understanding of these effects, offering deeper insights into the determinants of industrialization in emerging economies.

APPENDIX

A Tables

Table 4.A1: Correlation

	Industrialization	FDI	GDP per capita	Trade	Investment	Productivity	Service
FDI	-0.111*						
GDP per capita	-0.268*	0.167*					
Trade	-0.283*	0.299*	0.087*				
Investment	-0.283*	0.100*	-0.037	0.158*			
Productivity	-0.440*	-0.004	0.498*	0.043	0.160*		
Service	0.068*	0.177*	0.327*	-0.003	-0.167*	-0.035	
Capital	-0.271*	0.278*	0.367*	0.331*	-0.026	0.195*	0.325*

* for a significance at 5% level.

Table 4.A2: VIF Test of multicollinearity

Variable	VIF	1/VIF
Trade (log)	1.68	0,594
Productivity	1.49	0,673
Capital	1.42	0,703
Service (log)	1.31	0,764
Trade (log)	1.24	0,808
FDI	1.19	0,841
Investment (log)	1.11	0,904
Mean VIF	1.35	

Table 4.A3: Second-generation unit root test

		Level	First Difference
FDI	Zt-bar	-6.157	-19.795
	P-Val.	3.7E-10	1.64E-87
Capital	Zt-bar	-2.515	-10.1154
	P-Val.	0.006	2.36E-24
Productivity	Zt-bar	2.365	-15.3313
	P-Val.	0.991	2.36E-53
Industrialization (log)	Zt-bar	1.585	-13.8029
	P-Val.	0.944	1.22E-43
GDP per capita (log)	Zt-bar	-4.688	-12.6016
	P-Val.	1.38E-06	1.03E-36
Trade (log)	Zt-bar	-1.645	-13.7924
	P-Val.	0.050	1.42E-43
Service (log)	Zt-bar	-2.158	-14.15
	P-Val.	0.015	9.34E-46
Investment (log)	Zt-bar	-3.016	-16.0871
	P-Val.	0.001	1.57E-58

Table 4.A4: Co-integration test for panel data by Westerlund (2007)

Statistic	Value	Z-value	P-value	Robust P-value
Gt	-2.153	1.389	0.918	0.200
Ga	-5.357	5.295	1.000	0.970
Pt	-11.622	-0.484	0.314	0.150
Pa	-4.811	3.084	0.999	0.650

Table 4.A5: Country classification

Country group	Number of countries
Low Income Developping Countries (LIDC)	47
Emerging Markets (EM)	70
Advanced Economies (AE)	31
Total FMI	148
Non Classified	12
Total country	160

Table 4.A6: Regression table

Variables	(1) Industrialization FDI	(2) Capital	(3) Investment	(4) GDP per capita	(5) Trade	(6) Service	(7) Productivity
L.Industrialization	0.024 (0.047)	0.266 (1.395)	-0.038 (0.070)	0.038 (0.031)	-0.023 (0.021)	0.038 (0.031)	-0.003 (0.014)
L.FDI	0.004** (0.002)	0.624*** (0.072)	0.001 (0.005)	0.005** (0.002)	0.001 (0.001)	0.001 (0.001)	-0.000 (0.001)
L.Capital	-0.008 (0.006)	0.142 (0.132)	0.049 (0.043)	0.017** (0.007)	0.006*** (0.002)	-0.005 (0.012)	0.003 (0.004)
L.Investment	0.001 (0.028)	-0.152 (0.884)	0.018 (0.106)	0.785*** (0.037)	0.004 (0.015)	-0.068*** (0.019)	-0.009 (0.014)
L.GDP per capita	-0.141 (0.232)	15.276** (7.010)	0.651 (0.621)	0.440* (0.254)	0.123 (0.116)	-0.074 (0.111)	0.139 (0.124)
L.Trade	0.003 (0.027)	-0.781 (0.481)	0.285* (0.150)	0.065** (0.030)	0.043*** (0.013)	0.080** (0.037)	-0.043*** (0.010)
L.Service	-0.226* (0.126)	-11.806*** (3.120)	0.111 (0.154)	-0.022 (0.116)	-0.087*** (0.030)	0.055 (0.053)	0.050 (0.075)
L.Productivity	-0.142 (0.143)	-20.381*** (7.263)	-0.971* (0.545)	0.002 (0.222)	0.044 (0.102)	0.098 (0.085)	-0.152 (0.109)
Observations	996	996	996	996	996	996	996

Robust standard deviation in parentheses. Standard deviations have been clustered by country.

*** p<0,01, ** p<0,05, * p<0,1

J=68.815 (p = 0.318)

Table 4.A7: Variance decomposition by time

	t=0	t=1	t=2	t=3	t=4	t=5	t=6	t=7	t=8	t=9	t=10
Capital	0,000	0,000	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
FDI	0,000	0,013	0,018	0,019	0,020	0,020	0,020	0,020	0,020	0,020	0,020
GDP_pc	0,000	0,003	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009
Indus	0,000	0,983	0,956	0,954	0,953	0,953	0,952	0,952	0,952	0,952	0,952
Investment	0,000	0,001	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002
Productivity	0,000	0,000	0,000	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
Service	0,000	0,000	0,014	0,014	0,014	0,014	0,014	0,014	0,014	0,014	0,014
Trade	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

B Estimated Coefficient for the shocks

Table 4.B1: Estimated coefficient for Response of industrialization to macroeconomic shocks (Figure 4.3)

[illegible]

Table 4.B2: Estimated coefficient for Response of industrialization to macroeconomic shocks: After 2004 (Figure 4.4)

[illegible]

Table 4.B3: Estimated coefficient for Response of industrialization to macroeconomic shocks: 1990-2003 (Figure 4.5)

Variable	t0	t1	t2	t3	t4	t5	t6
IRF Coefficient							
Trade	0 (0, 0)	-.002 (-.009, .0044)	-.0037 (-.007, -.0001)	.0009 (-.0014, .003)	-.0004 (-.0017, .0009)	.0003 (-.0006, .0013)	.0001 (-.0006, .0008)
Service	0 (0, 0)	.011 (.004, .017)	-.005 (-.010, -.0008)	.0034 (.0004, .006)	.0003 (-.0016, .0022)	.0008 (-.0008, .002)	.0007 (-.0006, .002)
Capital	0 (0, 0)	-.011 (-.017, -.006)	-.0008 (-.005, .0037)	-.0017 (-.004, .0009)	-.0002 (-.0016, .0013)	-.0004 (-.0015, .0006)	0 (-.0008, .0007)
Indus	.071 (.065, .078)	-.008 (-.016, -.0001)	.004 (-.0001, .009)	-.0003 (-.003, .0026)	.0001 (-.0013, .0016)	0 (-.0011, .0011)	-.0001 (-.0008, .0005)
Productivity	-.0003 (-.0088, .0082)	-.003 (-.012, .0052)	.009 (-.001, .020)	.006 (-.0001, .013)	.0016 (-.004, .007)	.003 (-.0011, .008)	.0014 (-.002, .005)
FDI	.010 (.002, .019)	-.006 (-.018, .005)	-.0093 (-.016, -.002)	.0006 (-.004, .006)	-.003 (-.007, .0002)	-.0008 (-.004, .002)	-.0011 (-.0041, .0019)
GDP_pc	-.016 (-.025, -.007)	-.0252 (-.033, -.017)	.008 (.002, .013)	-.005 (-.009, -.0014)	.0001 (-.002, .002)	-.0004 (-.002, .0014)	-.0004 (-.0017, .001)
Investment	.007 (-.002, .016)	-.013 (-.023, -.0034)	.006 (-.0011, .013)	.0005 (-.005, .0066)	.003 (-.0017, .008)	.002 (-.002, .007)	.0026 (-.0018, .007)
Cumulative IRF coefficient							
Trade	0 (0, 0)	-.002 (-.009, .004)	-.006 (-.014, .0014)	-.005 (-.014, .0029)	-.006 (-.015, .003)	-.005 (-.015, .003)	-.005 (-.015, .004)
Service	0 (0, 0)	.011 (.004, .017)	.005 (-.0009, .012)	.009 (.0019, .016)	.009 (.0015, .017)	.010 (.0015, .018)	.010 (.0014, .020)
Capital	0 (0, 0)	-.011 (-.018, -.005)	-.0126 (-.018, -.0063)	-.014 (-.021, -.0074)	-.014 (-.021, -.006)	-.014 (-.022, -.006)	-.014 (-.023, -.006)
Indus	.071 (.065, .078)	.063 (.054, .073)	.068 (.059, .076)	.068 (.058, .077)	.068 (.058, .077)	.068 (.058, .077)	.068 (.058, .077)
Productivity	-.0003 (-.008, .008)	-.003 (-.015, .008)	.006 (-.010, .022)	.012 (-.007, .032)	.014 (-.009, .038)	.018 (-.009, .045)	.019 (-.010, .050)
FDI	.010 (.0019, .019)	.0041 (-.010, .018)	-.0052 (-.021, .010)	-.004 (-.024, .014)	-.008 (-.030, .014)	-.0093 (-.034, .015)	-.0104 (-.037, .016)
GDP_pc	-.016 (-.025, -.0077)	-.041 (-.052, -.030)	-.033 (-.045, -.021)	-.038 (-.051, -.026)	-.038 (-.052, -.025)	-.039 (-.053, -.025)	-.039 (-.054, -.025)
Investment	.007 (-.0022, .016)	-.006 (-.019, .0071)	-.0004 (-.017, .016)	.0001 (-.021, .021)	.0037 (-.021, .029)	.006 (-.022, .035)	.008 (-.023, .041)

Estimated coefficient and confidence interval in brackets

Table 4.B4: Estimated coefficient for Response of industrialization to macroeconomic shocks: before 1990 (Figure 4.6)

Variable	t0	t1	t2	t3	t4	t5	t6
IRF Coefficient							
Trade	0 (0, 0)	-.0018 (-.017, .013)	-.0018 (-.010, .007)	-.0001 (-.005, .005)	.0004 (-.005, .006)	.0004 (-.006, .0077)	.0003 (-.009, .0104)
Service	0 (0, 0)	-.004 (-.015, .005)	.0017 (-.006, .009)	-.0014 (-.007, .0044)	-.001 (-.005, .002)	-.0014 (-.006, .003)	-.0011 (-.0071, .004)
Capital	0 (0, 0)	-.0007 (-.018, .016)	-.0011 (-.009, .0071)	.0026 (-.0037, .008)	.002 (-.0044, .009)	.002 (-.006, .010)	.0015 (-.009, .012)
Indus	.112 (.099, .125)	.017 (-.002, .036)	-.006 (-.018, .006)	-.001 (-.011, .008)	-.0006 (-.013, .011)	-.0004 (-.017, .017)	-.0004 (-.025, .0252)
Productivity	.018 (.0002, .036)	.046 (.019, .073)	.007 (-.024, .040)	-.002 (-.036, .031)	-.0052 (-.048, .037)	-.005 (-.066, .054)	-.005 (-.094, .083)
FDI	-.019 (-.038, -.0015)	.018 (-.0077, .045)	.023 (-.002, .048)	.014 (-.011, .040)	.009 (-.020, .039)	.0063 (-.032, .044)	.0041 (-.050, .058)
GDP_pc	.031 (.012, .049)	-.035 (-.058, -.011)	.002 (-.014, .019)	.003 (-.008, .014)	.002 (-.008, .013)	.0014 (-.011, .014)	.001 (-.016, .019)
Investment	.029 (.0104, .048)	.0029 (-.027, .033)	.0077 (-.026, .042)	.005 (-.034, .045)	.003 (-.047, .055)	.002 (-.067, .072)	.001 (-.099, .102)
Cumulative IRF coefficient							
Trade	0 (0, 0)	-.0018 (-.017, .014)	-.003 (-.0252, .018)	-.0037 (-.027, .019)	-.0033 (-.029, .023)	-.0029 (-.035, .029)	-.0026 (-.045, .039)
Service	0 (0, 0)	-.004 (-.015, .006)	-.0029 (-.014, .008)	-.0044 (-.019, .010)	-.005 (-.023, .012)	-.0071 (-.029, .014)	-.0082 (-.036, .020)
Capital	0 (0, 0)	-.0007 (-.017, .016)	-.0017 (-.0241, .020)	.0009 (-.025, .027)	.0033 (-.028, .034)	.005 (-.033, .044)	.006 (-.045, .059)
Indus	.112 (.099, .125)	.129 (.106, .152)	.123 (.093, .153)	.122 (.086, .158)	.121 (.076, .166)	.121 (.059, .182)	.120 (.033, .208)
Productivity	.018 (.0005, .036)	.064 (.030, .099)	.072 (.013, .131)	.070 (-.019, .159)	.065 (-.065, .196)	.059 (-.136, .255)	.053 (-.247, .354)
FDI	-.019 (-.038, -.0017)	-.001 (-.035, .032)	.021 (-.0296, .073)	.036 (-.034, .108)	.046 (-.052, .144)	.052 (-.085, .190)	.056 (-.143, .256)
GDP_pc	.031 (.013, .048)	-.0041 (-.034, .026)	-.002 (-.036, .032)	.001 (-.038, .040)	.003 (-.043, .049)	.004 (-.052, .061)	.005 (-.068, .079)
Investment	.029 (.010, .048)	.032 (-.0033, .067)	.039 (-.023, .103)	.045 (-.053, .145)	.049 (-.098, .197)	.052 (-.165, .269)	.053 (-.270, .376)

Estimated coefficient and confidence interval in brackets

Table 4.B5: Estimated coefficient for Estimation using employment: After 2004 (Figure 4.7)

Variable	t0	t1	t2	t3	t4	t5	t6
IRF Coefficient							
Trade	0 (0, 0)	.004 (.0007, .007)	.0011 (-.0008, .003)	.0005 (-.001, .002)	.0002 (-.001, .0015)	0 (-.001, .0013)	0 (-.0013, .001)
Service	0 (0, 0)	-.008 (-.012, -.005)	.0002 (-.002, .0033)	.002 (-.0007, .004)	.001 (-.0019, .003)	.0007 (-.0026, .004)	.0002 (-.0033, .003)
Capital	0 (0, 0)	-.0022 (-.0055, .001)	.0002 (-.0015, .0019)	.0004 (-.0007, .0015)	.0005 (-.0006, .0015)	.0004 (-.0006, .0013)	.0003 (-.0006, .0011)
Indus	.031 (.029, .034)	.0026 (-.0019, .007)	0 (-.003, .003)	-.0008 (-.003, .002)	-.0009 (-.0033, .0016)	-.0005 (-.002, .0018)	-.0003 (-.0026, .0019)
Productivity	.003 (-.0002, .007)	-.002 (-.007, .0026)	-.0033 (-.011, .004)	-.0001 (-.007, .007)	-.0001 (-.0077, .007)	.0005 (-.006, .0077)	.0004 (-.006, .007)
FDI	-.0004 (-.0041, .0033)	-.003 (-.008, .0008)	-.004 (-.0088, .0002)	-.003 (-.0074, .0014)	-.0019 (-.006, .0026)	-.0009 (-.005, .0041)	-.0002 (-.005, .005)
GDP_pc	.003 (-.0007, .0066)	.002 (-.002, .0082)	-.0002 (-.004, .004)	.0013 (-.003, .006)	.0002 (-.004, .005)	0 (-.004, .004)	-.0002 (-.0052, .004)
Investment	.004 (.001, .008)	.0019 (-.003, .007)	.0017 (-.002, .005)	.0026 (-.001, .0063)	.0016 (-.002, .005)	.0013 (-.0029, .005)	.001 (-.003, .004)
Cumulative IRF coefficient							
Trade	0 (0, 0)	.004 (.0007, .007)	.005 (.0003, .009)	.005 (-.0001, .011)	.005 (-.0008, .012)	.005 (-.0014, .013)	.005 (-.0019, .013)
Service	0 (0, 0)	-.008 (-.012, -.005)	-.0088 (-.013, -.003)	-.006 (-.0126, -.001)	-.005 (-.013, .0015)	-.005 (-.014, .003)	-.004 (-.015, .006)
Capital	0 (0, 0)	-.0022 (-.005, .001)	-.002 (-.006, .002)	-.0016 (-.006, .003)	-.0011 (-.006, .004)	-.0008 (-.006, .004)	-.0005 (-.0063, .005)
Indus	.031 (.029, .034)	.034 (.029, .039)	.034 (.027, .041)	.033 (.024, .042)	.032 (.022, .042)	.032 (.020, .043)	.031 (.019, .043)
Productivity	.003 (-.0003, .007)	.0011 (-.0055, .0077)	-.0022 (-.0148, .010)	-.002 (-.021, .016)	-.002 (-.028, .023)	-.002 (-.032, .028)	-.0015 (-.036, .033)
FDI	-.0004 (-.0041, .0033)	-.004 (-.010, .0019)	-.008 (-.018, .001)	-.011 (-.024, .0016)	-.013 (-.029, .002)	-.014 (-.032, .003)	-.014 (-.035, .005)
GDP_pc	.003 (-.0006, .006)	.005 (-.001, .012)	.0055 (-.003, .014)	.006 (-.0066, .020)	.007 (-.010, .024)	.006 (-.014, .028)	.006 (-.017, .031)
Investment	.004 (.0013, .008)	.006 (-.0001, .013)	.008 (-.001, .018)	.011 (-.0003, .022)	.012 (-.0005, .026)	.014 (-.0009, .029)	.015 (-.0015, .031)

Estimated coefficient and confidence interval in brackets

5

Impact of FDI on Environmental Performance in Host Countries

Abstract: This study examines the effects of FDI inflows and stocks on environmental performance across 174 countries between 2001 and 2022. It distinguishes between groups of countries based on development level, geographic region, and trade bloc affiliation, offering a nuanced understanding of FDI's environmental impact. The findings show that FDI's influence on environmental outcomes is heterogeneous, varying significantly depending on the characteristics of the host and source countries. Developed economies, such as those in the EEA and the United States, exhibit mixed environmental effects from FDI. While some regions, including ASEAN and Latin America, benefit from improved environmental outcomes, others, particularly Sub-Saharan Africa and the MENA region, suffer from adverse effects. FDI stocks are generally associated with better environmental performance, especially in emerging economies such as those in ASEAN and Latin America. In these regions, long-term investments promote more sustainable practices. However, short-term FDI inflows are frequently linked to environmental degradation, particularly in resource-dependent economies with weak regulatory frameworks. The study emphasizes the need for host countries to strengthen environmental regulations to ensure that FDI promotes sustainable development. It also highlights the responsibility of source countries, especially in the developed world, to encourage investments that support green technologies and sustainable practices. The research contributes to the ongoing debate between the Pollution Haven and Pollution Halo hypotheses, suggesting that FDI can play a positive or negative role depending on the regulatory and institutional frameworks in place.

Keywords: Foreign Direct Investment (FDI), Environmental Performance, Sustainable Development, Globalization and Environment, Trade Blocs

JEL Codes: F18, F21, O13, Q56, Q58, O44

5.1 Introduction

In a globalized economy where interdependencies are deepening, Foreign Direct Investment (FDI) plays a crucial role in shaping the economic trajectories of host countries. FDI inflows not only improve infrastructure, create jobs, and enhance productive capacities but also carry potential environmental externalities ([Mensah and Traore, 2024](#); [Moore et al., 2024](#); [Khan et al., 2023](#); [Crescenzi et al., 2022](#); [Bashir, 2022](#); [Adeel-Farooq et al., 2021](#); [Demena and Afesorgbor, 2020](#)). While FDI may foster the transfer of cleaner technologies and sustainable practices, it may also encourage the relocation of polluting industries to regions with more lenient environmental regulations.

The theoretical and empirical debate on the relationship between FDI and environmental performance has been extensive. On the one hand, the Pollution Haven Hypothesis (PHH) posits that countries with lax environmental regulations attract pollution-intensive industries, as supported by several studies in emerging and developing economies (see, e.g., [Sarkodie and Strezov \(2019\)](#); [Wang and Liu \(2019\)](#)). On the other hand, the Pollution Halo Hypothesis (PHL) suggests that FDI can improve environmental quality by transferring advanced, cleaner technologies from developed to developing countries ([Pazienza, 2019](#); [Zhang, 2013](#)). This mixed evidence underlines the complex and nuanced nature of FDI's impact on the environment, depending largely on the host country's regulatory framework, level of development, and sectoral characteristics.

Empirical studies have shown varying results across different contexts. Some research confirms that stricter environmental regulations in developed countries, have led to a relocation of polluting activities to countries with weaker regulatory frameworks, validating the PHH ([Cai et al., 2016](#); [Zheng and Shi, 2017](#); [Hanif et al., 2019](#)). However, other studies have pointed to the importance of institutional quality in mediating the impact of FDI on environmental outcomes. Some authors found that transparent and stable regulatory frameworks in developing countries can attract cleaner FDI, aligning with the PHL ([Kirkulak et al., 2011](#); [Pazienza, 2019](#)).

Our study builds on this literature by providing a detailed analysis of the impact of FDI on environmental performance on host countries, focusing on both FDI flows and stocks. We analyze 174 countries over the period from 2001 to 2022, taking

into account regional differences, levels of development, and the role of trade blocs. By distinguishing between different groups of countries, such as high-income countries (HIC), middle-income countries (UMIC and LMIC), and low-income countries (LIC), as well as key trade blocs like the Association of Southeast Asian Nations (ASEAN), the North American Free Trade Agreement (NAFTA), and the Common Market for Eastern and Southern Africa (COMESA), we provide a nuanced understanding of how FDI influences environmental outcomes across different contexts.

Our descriptive analysis reveals that FDI inflows from developed countries, particularly from the European Economic Area (EEA) and the United States of America (USA), have mixed effects on the environmental performance of host countries. While some regions, such as ASEAN and NAFTA, benefit from FDI inflows that improve their environmental performance, others, such as the COMESA and the Southern African Development Community (SADC), experience negative environmental impacts due to their reliance on extractive industries and weaker environmental regulations.

In contrast, FDI stocks show a different pattern. We find that emerging markets, especially in the ASEAN and Latin America, benefit from higher FDI stocks, which are associated with better environmental performance. This suggests that long-term FDI investments in these regions may be linked to more sustainable projects. However, in regions like Sub-Saharan Africa (SSA) and the Middle East and North Africa (MENA), FDI inflows are often correlated with negative environmental impacts, highlighting possible immediate economic benefits but long-run environmental costs associated with these investments.

The policy implications of our findings suggest that attracting FDI should not come at the expense of environmental standards. Host countries must strengthen their regulatory frameworks to maximize the benefits of FDI while mitigating its negative environmental externalities. Additionally, developed countries and major FDI source economies should promote responsible investment practices that encourage the transfer of green technologies and support the transition to more sustainable development pathways.

The rest of our paper is organized as follows: Section 5.2 presents the literature review, then Section 5.3 develops the methodology, then Section 5.4 defines the

variables and data, Section 5.5 discusses the results, and Section 5.6 concludes.

5.2 Literature Review

The relationship between foreign direct investment (FDI) and environmental quality is multifaceted, with numerous mechanisms potentially leading to endogeneity in this interaction. In this literature review, we will explore the links between FDI and the environment.

5.2.1 FDI and environment

The relationship between FDI and environmental quality is bidirectional: FDI flows can influence the level of pollution or environmental regulations, but differences in environmental quality between countries or regions (in terms of pollution or regulations) can also shape the choice of location or relocation of foreign direct investments.

Environmental Regulation and FDI Attractiveness

According to the Pollution Haven Hypothesis (PHH), firms in developed countries, facing stricter environmental regulations at home, tend to relocate their polluting activities to less developed countries with more lenient environmental standards. Consequently, over time, developing economies could become pollution havens.¹ In their seminal work, Baumol and Oates (1988), using a two-country partial equilibrium model with two sectors characterized by different levels of pollution intensity, show that a country with stricter environmental regulations will have a "comparative disadvantage" in producing pollution-intensive goods. On the contrary, countries with more lenient regulations would have a "comparative advantage," making them more attractive for the production of such goods. Several theoretical works contribute to the development of this literature (Markusen et al., 1995, 1993, 1992; Motta and Thisse, 1994; Tang, 2015; Candau and Dienesch, 2017).

On the empirical side, the findings are more nuanced. Variations in methodology—such as model selection, study period, or the adoption of advanced econometric

¹Economists specializing in international trade use the term comparative advantage and propose that developing countries may have a comparative advantage in the production of pollution-intensive goods. For further details, see Gong et al. (2020); Brandi et al. (2020); McAusland (2010).

techniques like those in [Chichilnisky \(1994\)](#)—along with differences in the chosen variable to represent environmental policy stringency, sample characteristics (e.g., country-level vs. firm-level data), and the time frame of analysis, can all significantly impact the observed effects.

A substantial body of research supports the existence of the PHH. Through a difference-in-differences analysis allowing for exploration of three-dimensional variations (city, industry, year), [Cai et al. \(2016\)](#) confirm that the implementation of stricter environmental regulations in certain Chinese cities in 1998 led to a reduction in foreign direct investment (FDI). However, it is noteworthy that this effect did not appear to come from foreign multinationals originating from countries with stronger environmental protections than China; these firms seemed largely indifferent to the tightening of environmental regulations in the host country. By disaggregating data at the firm level across Chinese provinces and evaluating FDI flows, [Wang et al. \(2019\)](#) also validated the PHH for the period 2011-2015.

Several other studies confirm the existence of the PHH in various contexts. [Sarkodie and Strezov \(2019\)](#), in a study covering five major greenhouse gas emitters, including China, India, Iran, Indonesia, and South Africa (from 1982 to 2016), lend support to the PHH. Similar findings are presented by [Shahbaz et al. \(2019\)](#) for Middle Eastern and North African countries (1990 to 2015), by [Nasir et al. \(2019\)](#) for ASEAN emerging economies, by [Chung \(2014\)](#) for Korean FDI, by [Kheder and Zugravu \(2012\)](#) for French FDI, by [Hanna \(2010\)](#) for the United States, and by [Wagner and Timmins \(2009\)](#) for Germany.

While a portion of the literature corroborates theoretical predictions, other studies nuance this effect. For example, [Kirkpatrick and Shimamoto \(2008\)](#) show that Japanese FDI in five pollution-intensive industries appears to be located in countries committed to a transparent and stable environmental regulatory framework. In fact, the authors argue that “the quality of the regulatory framework in terms of its certainty and transparency has a greater influence on foreign investors’ choice of location than the level of environmental regulatory measures”. [Tole and Koop \(2011\)](#) reach similar conclusions to [Kirkpatrick and Shimamoto \(2008\)](#).

Finally, some studies refute the validation of the PHH, suggesting that environmental factors have no effect on FDI. [Shao et al. \(2019\)](#) reject the PHH using a panel

vector error correction (VECM) model and a panel co-integration test for two groups of countries—BRICS (Brazil, Russia, India, China, and South Africa) and MINT (Mexico, Indonesia, Nigeria, and Turkey)—over the period 1982 to 2014. Other studies such as [Manderson and Kneller \(2012\)](#) investigating on outward FDI by British firms, [Dean et al. \(2009\)](#) analyzing the Chinese case, [Raspiller and Riedinger \(2008\)](#) on French firms, and [Javorcik and Wei \(2003\)](#) the 25 economies in Eastern Europe and the former Soviet Union also fall into this category.

Effects of FDI on Environmental Quality

The heterogeneity of empirical studies has led to an alternative way of understanding the impact of FDI on environmental quality. Given that the majority of FDI flows originate from developed countries, which generally have stricter environmental policies compared to developing countries, multinationals from developed economies are more likely to have access to “cleaner” technologies than those available in developing nations. According to the Pollution Halo Hypothesis (PHL), rather than contributing to environmental degradation, FDI could facilitate the transfer of these advanced and environmentally-friendly technologies, along with better environmental standards.

To test this hypothesis, most studies have focused on OECD countries ([Cole et al., 2017](#); [Zhang, 2013](#)), aiming to either validate or disprove the Pollution Halo Hypothesis (PHL). The PHL posits that developed countries transfer technologically advanced, environmentally friendly FDI and higher environmental standards to developing economies. Consequently, FDI from developed economies is seen as a driver of improved environmental quality in host developing countries. However, with the rise of FDI originating from the Global South, particularly South–South flows (e.g., from China to Africa), an increasing number of studies have shifted their focus to emerging economies, especially China ([Zhang, 2013](#)). These studies, whether conducted at the aggregate level (i.e., country or region) or at the micro level (i.e., firms), present mixed findings.

Moreover, [Kirkulak et al. \(2011\)](#) found that FDI presence reduces air pollution in China, using data from 286 cities between 2001 and 2007 (cross-sectional, time series, and panel data approaches – fixed and random effects). [Pazienza \(2019\)](#)

reached similar conclusions, showing that FDI in the manufacturing sector of OECD countries reduced CO₂ emissions from sectoral fuel combustion over the 1989–2016 period, even as FDI contributed to the growth of the manufacturing sector. He attributed this positive environmental effect to the role of FDI as a driver of technological innovation and a mechanism for implementing greener and cleaner production methods.

However, these results are contradicted by studies focusing on poorer countries. [Doytch and Uctum \(2016\)](#) show that in such contexts, FDI has a detrimental impact on the environment. Additionally, in a study of 15 developing Asian countries from 1990 to 2013, [Hanif et al. \(2019\)](#) confirmed the PHH effect and rejected the PHL, showing that FDI in developing countries is a major source of CO₂ emissions (see also [Essandoh et al. \(2020\)](#), for low-income countries). Similarly, [Lau et al. \(2014\)](#) found that FDI in Malaysia increases CO₂ emission levels.

Nevertheless, several mechanisms seem to modify the FDI-environment relationship. [Cole et al. \(2006\)](#), in a study of 33 countries (including 13 OECD countries and 20 developing nations) between 1982 and 1992, show that the impact of FDI on the environment depends on the degree of government corruption in the host countries. [Lan et al. \(2012\)](#), in a study on China, also found that the impact of FDI on pollution emissions heavily depends on the level of human capital.

The validation of the PHH paradigm may also depend on various environmental policies and industrial characteristics ([Zheng and Shi, 2017](#)). Moreover, other factors such as corporate social responsibility ([Bu et al., 2013](#)), institutional quality and natural resources ([Huynh and Hoang, 2019](#); [Dam and Scholtens, 2012](#)), the stringency of environmental policies ([Wang and Liu, 2019](#); [Manderson and Kneller, 2012](#)), as well as wealth levels ([Duan and Jiang, 2021](#); [Doytch and Uctum, 2016](#)) and the level of development ([Adeel-Farooq et al., 2021](#); [Singhania and Saini, 2021](#); [Zhang and Wang, 2021](#); [Balsalobre-Lorente et al., 2019](#); [Doytch and Uctum, 2016](#)), and the sector ([Doytch and Uctum, 2016](#)) could also influence this relationship. In this regard, [Zugravu-Soilita \(2017\)](#) highlights the existence of conditional effects of FDI on industrial emissions, suggesting that the “Pollution Haven”, “Factor Endowments”, and “Pollution Halo” hypotheses may operate simultaneously with opposing effects.

5.2.2 FDI and the Environmental Performance Index (EPI)

Recent studies examining the impact of FDI on the environment use the Environmental Performance Index (EPI) developed by the Yale Center for Environmental Law and Policy (Wolf et al., 2022). This measure accounts for various aspects of a country's environmental quality, such as ecosystem vitality (biodiversity and habitat, ecosystem services, fisheries, acidification, agriculture, water resources), environmental health (air quality, sanitation and drinking water, heavy metals, waste management), and regulatory objectives related to climate change. The EPI is particularly valuable as it provides a more comprehensive and representative view of a country's environmental health compared to single or sectoral measures, such as CO2 emissions.

As with previous research, the reported effects of FDI on environmental outcomes are heterogeneous, which may partially be due to differentiated results across groups of countries. For instance, Bernard and Mandal (2016) found no significant impact of FDI on EPI for developing and emerging countries. In contrast, Gao and Li (2023) reports a positive effect when focusing on FDI flows from China to countries involved in the Belt and Road Initiative. These positive effects also appear within China, in the case of inter-provincial FDI flows (Zhang et al., 2023).

Li et al. (2019) shows that the positive effects of FDI in developed countries are conditional upon these countries already having a good environmental performance. In these countries, the positive effects of FDI increase with higher quantiles of EPI and are significantly positive only for the middle and high quantiles. According to Li et al. (2019), "the benefits from FDI are diverse because of the countries' different absorptive capacity".

This pattern appears to be confirmed by Tsoy and Heshmati (2023), who, using a comprehensive sample of 60 countries from Asia, Latin America, Europe, and Africa, identifies a U-shaped correlation between FDI inflows and EPI. Tsoy and Heshmati (2023) demonstrates that a high level of FDI inflows worsens environmental quality at first, but improves it later as the FDI inflow surpasses a critical turning point. According to Tsoy and Heshmati, such a *relationship may arise from the initial promotion of 'dirty' FDI from developed countries that degrade environmental quality until a threshold is reached, after which "green" FDI improves environmental*

outcomes.

5.3 Methodology

In this study, we thoroughly examine the influence of foreign direct investment (FDI) on environmental performance while taking into account the characteristics of both the home and host countries. To analyze these complex relationships, we specify our general linear panel regression model as follows:

$$Env_{it}^h = \beta_0 + \beta_1^o FDI_{it}^o + \beta_2^k X_{it}^k + \mu_{it} \quad (5.1)$$

where $\mu_{it} = \eta_i + \tau_t + \epsilon_{it}$. The index i represents the country, and t denotes time. η_i captures country-specific fixed effects that are invariant over time for each country i , and τ_t represents time-specific fixed effects common to all countries but varying over time. ϵ_{it} is the idiosyncratic error term, assumed to be independently and identically distributed.

The variable Env measures the environmental performance level of country i at time t within group h , where h denotes the host countries group. It reflects the country's environmental quality by considering ecosystem vitality, environmental health, climate change, and policy objectives.

FDI_{it}^o represents the net FDI flows and/or stocks entering country i at time t from partner (or home, or origin) countries group, denoted by o . Throughout our analysis, we employ lagged values of FDI flows or stocks to address potential endogeneity issues (Cole et al., 2006). The same approach is applied to the other control variables in order to obtain causal estimates and conduct a more robust analysis of our explanatory variables.

The heterogeneity in host and origine of FDI flows is captured by differentiating the characteristics of these flows based on the type of country groups involved. The flows are categorized by the host country group, indexed by h , and the source country group, indexed by o , such that the flow direction is represented as $o \rightarrow h$ (origin countries-group $\rightarrow$ Host countries-group). Countries are grouped based on geographic position (North vs. South), development level, regional classification, and membership in trade blocs. Significant differences in economic and political development levels between Northern and Southern Hemisphere countries may in-

fluence the nature of intra- and inter-group FDI effects (Ahouangbe and Turcu, 2024; Demir and Duan, 2018). Moreover, the literature suggests that both the development level of the source country and the host country receiving FDI can have implications for environmental outcomes (Adeel-Farooq et al., 2021). Furthermore, within regions, regulatory frameworks tend to be more homogenous, and preferential agreements may exist within or between trade blocs, suggesting potential regional or trade bloc-specific FDI effects.

In this analysis, the key coefficient of interest is β_1 , which estimates the impact of FDI from country groups o (origin group) on host country groups h .

The vector X represents a set of k control variables, including: 1) the development level, to capture the wealth effect, assuming that wealthier nations will demand a cleaner environment by pressuring their governments (in line with the Environmental Kuznets Curve hypothesis), 2) the urbanization rate, which controls for the increased exposure to industrial pollution faced by more urbanized populations, 3) the size of the manufacturing sector, as a proxy for the presence of highly polluting industries, and 4) the share of renewable energy consumption, reflecting the energy structure and how a country addresses environmental challenges through cleaner energy sources.

Additionally, where possible and to improve model specification, we include squared terms of control variables to account for potential threshold effects. The square of the “development level” allows for testing the Environmental Kuznets Curve hypothesis, while the squared terms of other variables address possible nonlinearities (Mahmood et al., 2023; Ansari, 2022; Leal and Marques, 2022; Potters and Sloof, 1996).

We assess how FDI flows between different groups impact environmental outcomes, considering both linear and non-linear relationships driven by development, urbanization, and renewable energy consumption.

5.4 Variables and data

Our data comes from various databases. Environmental performance is captured by a composite index that aggregates several indicators grouped into three categories: *Ecosystem vitality*, *Environmental health*, and *Climate change policy*

objective. These categories are further generated from weighted subcomponents calculated from 40 indicators. Table 5.A1 in Appendix A outlines the various components of each category. The compiled data is published by SEDAC (Socioeconomic Data and Applications), originally prepared by the Yale Center for Environmental (Yale and CIESIN, 2022). The EPI (Environmental Performance Index) calculation methods have evolved over time due to the inclusion of new indicators. Given the potential bias that such changes might introduce, we utilized the 2022 EPI calculation methodology on the primary and historical data of the 40 indicators to reconstruct the EPI values across time (Wolf et al., 2022). This approach ensures comparability over time using a single calculation method. The index ranges from 0 (extremely poor environmental performance) to 100 (excellent environmental performance).

Incoming FDI net flows represent transactions made by foreign investors in resident enterprises of the reporting host economy, less any transactions that reduce foreign investors' equity in resident firms. In contrast, incoming FDI net stocks represent the total value of foreign investors' holdings, including net loans provided to enterprises residing in the reporting economy. Data on FDI net flows and stocks come from the World Bank's harmonized bilateral FDI databases (Steenbergen et al., 2022). It covers the period from 2001 to 2021. We exploit this bilateral database to generate total flows and stocks for various partner groups (p , group of origin countries) for each host country i . The data is expressed in millions of USD². We deflate the FDI by the U.S. GDP deflator to account for changes in dollar price levels, making the values internationally comparable.

To account for and evaluate the heterogeneity of FDI flows and stock's origin and destination, we employ multiple classification schemes. First, we distinguish between countries based on *geographic position* (North vs. South). The Northern countries are defined as members of the OECD, while Southern countries are non-OECD members. Second, in terms of *development levels*, we apply the World Bank's classification, which divides countries into four income groups based on GDP per capita: high-income (HI), upper-middle-income (UMIC), lower-middle-income (LMIC), and low-income countries (LIC). Furthermore, we consider the IMF's classification into *three types of markets and economies*: Advanced Economies (AE),

²We will perform unit transformations as required depending on the analysis objectives.

Emerging Markets (EM), and Low-Income Developing Countries (LID).

For the regional grouping, we follow the World Bank's division into *seven regions*: Latin America & the Caribbean (LAC), South Asia (SA), Sub-Saharan Africa (SSA), Europe & Central Asia (ECA), Middle East & North Africa (MENA), East Asia & Pacific (EAP), and North America (NA). Finally, regarding *trade blocs*, we define 10 trade blocs (TEA, Trade Economic Area)³, including the European Economic Area (EEA), the North American Free Trade Agreement (NAFTA), Mercado Común del Sur (MERCOSUR), Association of Southeast Asian Nations (ASEAN), Common Market for Eastern and Southern Africa (COMESA), Asia Pacific Economic Cooperation (APEC), South Asian Association for Regional Cooperation (SAARC), Indian Ocean Rim Association (IORA), Latin American Integration Association (LAIA), and the Southern African Development Community (SADC). For each grouping, except for explicitly defined trade blocs and the North-South division, we create an "Other" class when information is missing or when it is difficult to assign a country to a specific group.

In the global analysis, a "ALL"⁴ category is created, taking the value of 1 for all countries in our sample. Thus, by definition, we have: $o = h = \{\text{ALL, North, South, HI, UMIC, LMIC, LIC, Other (Income Grp), AE, EM, LID, Other (Eco), LAC, SA, SSA, ECA, MENA, EAP, NA, Other (Region), EEA, NAFTA, MERCOSUR, ASEAN, COMESA, APEC, SAARC, IORA, LAIA, SADC}\}$. The number of possible flow types, $h \times o$, represents all possible combinations, where for each host country group h , all origin country groups o are considered⁵. For example, a possible combination is "ALL – North" (in the format $o - h$), indicating the total net flow (or stock) from all countries worldwide (o , origin) into a Northern country (h , host). Table 5.A2 in Appendix A presents the distribution of countries in the origin groups we constructed from 251 countries (including islands) to calculate the aggregated FDI flows and stocks. This approach has the advantage of allowing for the analysis of both intra-group (e.g., South-South) and inter-group (North-South) effects of FDI on the environment.

The control variable data primarily come from the World Bank's World Devel-

³A country can belong to multiple trade blocs, which does not pose any issues for our analysis.

⁴ALL represents the World.

⁵In practice, fewer than $o \times h = o^2 = h^2$ combinations might be realized due to the exclusion of certain small groups in the data or when the sample size is too small for panel regression.

opment Indicators (WDI) database. Economic development is measured by GDP per capita in constant 2015 \$US. Urbanization rate is defined as the percentage of the total population living in urban areas. The manufacturing sector is captured by the share of manufacturing value added as a percentage of GDP. Renewable energy consumption intensity⁶ is measured as the share of renewable energy in total final energy consumption.

For this study, we focus on the period from 2001 to 2021 (21 periods) due to the availability of the key variable of interest, *Foreign Direct Investment* (FDI). We include only countries with at least 16 observations (or 70% of the period). For countries lacking data at the beginning or end of the period (the first 3 years: 2001 to 2003, and the last 3 years: 2019 to 2021), we impute missing data using the average annual growth rate⁷ from the last five years. Except for FDI flows, other variables are not highly volatile over long periods. However, they often exhibit a constant growth rate, determined by the structure of each economy.

Introducing lagged variables results in the loss of one year and a reduction in sample size. To maintain the same number of periods, we crudely extend the dataset to include 2022, allowing us to retain 2021 data (which would otherwise be lost due to lagging) in our specification. After processing, our sample consists of 174 countries (host) over the 2001 to 2022 period.

5.5 Results and discussion

Table 5.A3 presents descriptive statistics for the various variables introduced into our model. It includes key indicators such as FDI inflows and stocks, environmental performance, and control variables like GDP per capita, urbanization rate, and renewable energy consumption. These descriptive statistics provide a general overview of the dataset and highlight the heterogeneity among countries and periods.

Additionally, the correlation matrix is presented in table 5.A4, showing the relationships between the variables. To further assess the potential issue of multicollinearity, we conducted a Variance Inflation Factor (VIF) test. The average VIF

⁶While we follow a similar approach to [Ahouangbe and Turcu \(2024\)](#), we substitute total energy consumption with renewable energy consumption. The data on energy consumption stop in 2014, and renewable energy consumption provides a better measure of a country's environmental efforts.

⁷For the initial years (2001 to 2003), we calculate the average annual decreasing rate and impute values in reverse, meaning we apply it from 2003 back to 2001.

result is 1.84, suggesting that multicollinearity is not a significant concern in our data. A VIF value below 10 typically indicates an acceptable level of correlation among the explanatory variables, ensuring that the regression results are not distorted by collinearity issues.

The results from the VIF test and correlation matrix provide confidence in the reliability of the econometric models used in subsequent sections.

5.5.1 Descriptive Analysis

Our descriptive analysis focuses on EPI and FDI flows and stocks, as well as the relationship between the two (EPI and FDI).

EPI

The Figure 5.B1 illustrates the global evolution of the Environmental Performance Index (EPI) across different country groups. Overall, the EPI shows an upward trend over our study period, with varying growth rates depending on the country group. Some groups experience significant growth, while others demonstrate modest increases or stagnation. Small islands and territories (Other Income denotes by Other Inc. on the figure) consistently exhibit the highest environmental performance levels.

Apart from small islands, the countries with stronger economic development, such as the European Economic Area (EEA), Advanced Economies (AE), Northern countries, Europe & Central Asia (ECA), and high-income countries (HIC), particularly within the NAFTA region, perform better. Generally, these countries record EPI scores above 50 points starting in 2020. Notably, between 2008 and 2016, these countries experienced significant growth in their environmental performance, while developing countries exhibited weaker growth or stagnation. Figures 5.B2, 5.B3, 5.B4, 5.B5, 5.B6 available in the appendix, display the evolution of environmental performance by different country groups.

Among developing countries, the global South stands out for its stagnant environmental performance. Specifically, groups such as Low-Income Developing Countries (LID) (Figure 5.B3), South Asia (Figure 5.B2), and Lower-Middle-Income Countries (LMIC) and Low-Income Countries (LIC) (Figure 5.B5) show limited progress. A notable trend is observed in the NAFTA region, mainly due to Mexico's catch-up efforts. Mexico's EPI score rose from 31.8 in 2008 to 44.67 in 2018, narrowing the

gap with the other NAFTA members (USA and Canada).

FDI: flow and stock

Figure 5.B7a shows the evolution of FDI inflows over the study period. FDI flows appear highly volatile throughout, with significant peaks in 2007, 2013, and 2015, followed by substantial declines in 2010, 2014, and 2018 due to major macroeconomic crises and events. Starting in 2017, there is a marked decline in FDI inflows, eventually reaching stagnation at levels similar to those at the beginning of the period, even for high-income countries (HIC). Overall, the most developed economies (mainly HIC, AE, North, followed by APEC and EEA) appear to dominate investments.

In contrast, Figure 5.B7b illustrates the evolution of net FDI stocks. It reveals continuous growth throughout the period, which, unlike FDI flows. The most developed economies (HIC, AE, North) largely dominate the FDI stock being the most attractive destinations for investors and able to retain FDI over the long term. On the other hand, lower- and middle-income economies gather lower FDI stocks compared to the richer economies. This reflects the challenges these economies face in securing long-term FDI inflows.

Despite the volatility of FDI flows, FDI stocks have consistently increased, especially in wealthier countries, positioning them as the preferred destinations for foreign direct investment.

Relationship between EPI and FDI (inflow and stock)

Table 5.A5 presents the average values over the studied period for EPI, FDI flows, and net FDI stocks across different country groups. To better understand the relationship between these three variables, we summarize the information in three figures: Figure 5.B13, Figure 5.B14, and Figure 5.B15. Figure 5.B15 illustrates the relationship between net FDI flows and net FDI stocks. It clearly shows that country groups with higher net FDI inflows also tend to accumulate larger FDI stocks.

Figure 5.B13 presents the relationship between net FDI inflows and environmental performance, while Figure 5.B14 depicts the relationship between net FDI stocks and environmental performance. While these two figures could be interpreted differently, both results suggest that country groups with higher EPI scores tend to attract and accumulate more significant amounts of FDI, both in terms of flows

and stocks. This confirms that countries with high environmental performance are preferred destinations and zones for FDI accumulation. For example, developed country groups like Europe (EEA), AE, North, and high-income countries (HIC) tend to exhibit high levels in all three indicators: EPI, FDI flows, and FDI stocks. Conversely, developing countries (LID) and low-income countries (LIC), such as those in Sub-Saharan Africa (SSA) and South Asia (SA), display low EPI scores and attract less FDI (both flows and stocks).

However, the correlation appears mixed for certain country groups, particularly: (i) APEC, ASEAN, IORA, and EAP (*Quadrant A*); (ii) NAFTA and NA (*Quadrant B*); and (iii) LAC, Other Eco, Other Reg, and Other Inc (*Quadrant D*). *Quadrant B*: The North American groups, including NAFTA and NA, have moderate EPI scores (44.07 and 47.74, respectively) but attract and accumulate significantly more FDI (Flows: \$102,017 million and \$138,815 million, respectively; Stocks: \$1,251,187 million and \$1,723,189 million, respectively) than other developed countries. Their relatively lower EPI scores may be due to the inclusion of low-EPI countries like Mexico (NAFTA) and Bermuda (NA), which drag down the group average. *Quadrant A*: The APEC, ASEAN, IORA, and EAP groups share several countries⁸, including advanced economies (such as the United States, Australia, and Japan), emerging economies (such as Indonesia and Vietnam), and primarily developing countries. The majority of developing and emerging countries pulls the environmental performance down, while the presence of advanced and emerging countries boosts the average FDI figures. Indeed, a small group of developed countries likely concentrate a significant portion of FDI within the group. The standard deviation values for these groups are substantial (see Table 5.A5). *Quadrant D*: The LAC, Other Eco, Other Reg, and Other Inc groups consist primarily of small countries, which raises the group's average EPI. However, as they are predominantly developing countries, their FDI levels remain low.

5.5.2 Model specification

To correctly specify our empirical model, we employ the regression methods presented in Table 5.A6 for the results with FDI net inflows and Table 5.A7 for the

⁸Indonesia, Malaysia, Thailand, Singapore, Vietnam, and Brunei Darussalam are members of both APEC, ASEAN, and EAP. Australia is a member of APEC, IORA, and EAP. Singapore belongs to all four groups: APEC, ASEAN, IORA, and EAP.

results with FDI net stocks. Specifically, we employ (i) grouped panel regressions (OLS, columns 1-4), (ii) fixed-effects panel regressions (FE, columns 5-8), and (iii) random-effects panel regressions (RE, columns 9-12). For each method, we estimate four different regression forms, divided into two blocks. The first block contains regressions without the squared control variables (columns 1, 3, 5, 7, 9, and 11), while the second block introduces the squared control variables to account for potential threshold effects (columns 2, 4, 6, 8, 10, and 12). In each block, we include or omit fixed effects (country or year) to account for the presence or absence of fixed effects.

The results of the tests conducted in both tables converge in our model specification. Therefore, we will comment in the following paragraph the results from Table 5.A6.

Using the grouped OLS regressions, we test for the presence of country or year fixed effects. The results of the joint Fisher significance test are presented in columns 3-4. We reject the null hypothesis of no fixed year effects (Column 3: F-Stat = 3.52, p-value = 0; Column 4: F-Stat = 4.05, p-value = 0) and country effects (Column 3: F-Stat = 75.77, p-value = 0; Column 4: F-Stat = 73.67, p-value = 0). This suggests that using appropriate panel methods (FE or RE) would yield more efficient estimators. To choose between FE and RE regressions, the Hausman test statistics presented in columns 9 (columns 5 vs. 9: Stat = 246.26, p-value = 0), 10 (6 vs. 10: Stat = 29.10, p-value = 0), 11 (7 vs. 11: Stat = 214.03, p-value = 0), and (8 vs. 12: Stat = 269.10, p-value = 0) suggest that fixed-effects regressions are preferred over random-effects regressions.

Comparing the different types of FE regressions, selection criteria such as the Root Mean Square Error (RMSE), Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) show lower values for regressions with country and year fixed effects and the inclusion of the squared control variables. This suggests that this specification predicts better and provides more informative variables. Thus, this will serve as our baseline interpretation.

However, an important note concerns our control variables.⁹ Therefore, we ex-

⁹Unlike [Ahouangbe and Turcu \(2024\)](#), who validated quadratic specifications in their study on environmental convergence, this analysis on environmental performance appears to favor a linear relationship. For instance, when the variable *Renewable energy consumption* is squared, the squared term is often not significant and tends to retain the same sign as the variable in its linear form. A similar observation applies to the *Urban population rate*.

amine regressions without the squared terms for these variables. The results are presented in Table 5.A8 for inflows and Table 5.A9 for stocks. For subsequent analysis, we retain the regressions excluding the squared terms for the Urban population rate and Renewable energy consumption.

The standard errors are clustered at the country level to account for serial autocorrelation within each country. Additionally, to avoid excessive exponentiation in the tables, we transform the units of FDI inflows and stocks into billions.¹⁰

5.5.3 Baseline empirical results

Overall, our results (see Tables 5.A6, 5.A7, 5.A8, and 5.A9) indicate that the coefficients associated with FDI net inflows are generally negative but statistically insignificant. This suggests that FDI net inflows do not have a significant impact on environmental performance. For FDI net stocks, the coefficients are positive but mostly insignificant across most specifications. This suggests some uncertainty about whether FDI stocks tend to be concentrated in regions where environmental performance is already good, aligning with the *Pollution Halo Hypothesis* (Eskeland and Harrison, 2003; Kirkulak et al., 2011).

The coefficient for GDP per capita is highly significant and negative across nearly all columns (both FDI flows and stocks). However, the effect of the square of GDP per capita is mixed, sometimes insignificant or weak. This suggests that the non-linear effect of GDP per capita may not be particularly robust in this context. The results indicate that at low levels of income or development (low GDP per capita), the economic development adversely affects environmental performance, but beyond a certain threshold, further economic development seems to have a neutral or positive impact. This might support the existence of an Environmental Kuznets Curve (EKC) (Grossman and Krueger, 1991). Beyond this threshold, wealthier countries are able to reduce environmental degradation as they prioritize environmental regulations and clean technologies.

The impact of urbanization is relatively weak and insignificant across all columns (see Tables 5.A8 and 5.A9), for both FDI flows and stocks. This suggests that urbanization does not have a direct observable effect on environmental performance,

¹⁰The actual values expressed in millions are divided by 1,000 (/1000) to express the values in billions.

contrary to much of the existing literature, which often finds negative environmental effects associated with urbanization (Cole et al., 2006). One possible explanation for this discrepancy is that our study spans a longer period compared to previous studies that focused on shorter timeframes. Over a longer horizon, the negative effects of urbanization may dissipate as countries implement stricter environmental policies.

The level of industrial development has a negative and sometimes significant impact (column 2 of FDI flows and column 2 of FDI stocks). However, the quadratic variable for the manufacturing sector (*Manufacturing*) shows a positive and significant effect in several models, suggesting a non-linear U-shaped relationship. This implies that at lower levels of industrialization, the manufacturing sector negatively impacts the country's environmental ecosystem. However, beyond a certain level of industrial development, particularly when manufacturing value-added becomes substantial, the production process becomes less polluting. This can be explained by the adoption of clean technologies, as countries with more advanced manufacturing sectors have a greater ability to innovate and incorporate green technologies. This corroborates the findings of previous studies, which highlight the challenges developing countries face in innovating and adopting green technologies due to regulatory costs and compliance challenges (Doytch and Uctum, 2016; Hanif et al., 2019).

Interesting insights can be derived from the degree of renewable energy consumption related results. The coefficient of this variable is positive and highly significant across nearly all specifications (columns 1 and 3 for FDI flows and columns 1 and 3 for FDI stocks). This suggests that countries with higher renewable energy consumption significantly improve their environmental performance. Additionally, the relationship between environmental performance and energy consumption appears to be linear.

In Table 5.A10, we simultaneously incorporate and interact FDI flow and stock variables. The results align with our baseline findings, suggesting that aggregate FDI (flows and stocks) does not significantly impact environmental performance. These findings are consistent with the ambiguous effects of FDI on the environment noted in the literature, where both the *Pollution Haven Hypothesis* and *Pollution Halo Hypothesis* are supported by different contexts and conditions (Baumol and

Oates, 1988; Sarkodie and Strezov, 2019; Wagner and Timmins, 2009).

5.5.4 Heterogeneity of FDI Flows and Stocks

The heterogeneity of different types of FDI flows and stocks is highlighted in Tables 5.A11 and 5.A12. The rows represent the groups of FDI-origin countries, while the columns reflect the FDI-hosting country groups.

Overall, the more aggregated the analysis (e.g., ALL, North, South), the harder it becomes to clearly identify the effects of FDI flows and stocks. However, when the analysis is more granular, focusing on specific groups or regions, the heterogeneous effects of FDI become more apparent. This suggests that it is crucial to distinguish between the different origins and destinations of FDI flows to better understand their specific impacts. A finer-grained analysis of FDI provides better insights into the diversity of its effects depending on regional and contextual factors

FDI Impact by Host Country Group

The first row of each table presents the overall impact of FDI on environmental performance across different groups of recipient countries (in columns), regardless of the source of FDI (ALL). This allows us to identify which groups of host countries are generally affected (positively or negatively) or unaffected by FDI flows or stocks in terms of environmental performance.

On a more aggregated level, FDI flows and stocks seem to have no significant effect (ALL $\rightarrow$ ALL), nor when we distinguish between host countries from the South or the North. However, when countries are grouped by their economic development, region, or trade bloc, specific effects emerge.

Our results reveal that FDI stocks have a generally positive and significant impact on the environmental performance of middle-income countries (UMC), emerging markets (EM), and specific regions such as the Middle East and North Africa (MENA), and trade blocs like COMESA and LAIA. In contrast, the impact of FDI flows is more variable, showing positive effects for groups like Other Economies, ASEAN, and NAFTA, but negative effects for the MENA region. For example, FDI flows have a particularly favorable impact on environmental performance in newly emerging South Asian countries (ASEAN: 0.028), such as Vietnam and Cambodia, as well as in small island states (Other Economies: 0.022). However, there is a notable negative effect for Middle Eastern and North African countries (MENA:

-0.043).

In the MENA region, countries with good environmental performance tend to attract higher FDI stocks, while large FDI flows are directed toward countries with weaker environmental performance, potentially making this region a “pollution haven”. On the other hand, FDI flows positively impact the environmental performance of small island states (Other Economies), regardless of the level of FDI stock.

FDI Impact by Origin Country Group

The first column of each table illustrates the impact of FDI originating from different groups of origin countries (in rows), irrespective of the group of host countries (ALL). This column allows us to identify which groups of origin countries’ FDI influence (positively, negatively, or neutrally) the environmental performance of recipient countries.

The results reveal significant heterogeneity in the ability of origin country groups to affect the environmental performance of their partners. FDI from the MENA region tends to have a strongly negative effect (-0.039) on the environmental performance of host countries, suggesting that such investments may be associated with sectors or industries that are less environmentally friendly. In contrast, FDI from MERCOSUR (0.097), ASEAN (0.043), and NAFTA (0.045) generally have a positive impact on the environmental performance of partner countries, which could indicate support for more eco-friendly projects or low-carbon sectors in recipient regions. These findings also suggest that American countries (MERCOSUR and NAFTA) might consider the ecological aspects of the investments they make.

Heterogeneity Across Host and Origin Country Groups

Overall, an overview of the Tables [5.A11](#) and [5.A12](#) suggests that FDI stocks tend to have a generally more positive effect on environmental performance, while FDI flows present more heterogeneous results. Some regional groups benefit more than others from FDI, with small island nations, ASEAN, and NAFTA often showing positive impacts from FDI, while the MENA region seems to suffer from large capital inflows that contribute to poorer environmental performance.

Among the groups of FDI origin countries, FDI from developing nations, flows from particularly those in the South, low-income countries (LIC), and the LAC

(Latin America and the Caribbean) group, have a positive and significant impact on the environmental performance of several of their partners. These FDI inflows contribute to improving the environmental performance of partner countries, especially in Asia and Africa. Additionally, FDI flow the NA (North America) group shows positive significant effects on environmental performance of low-income countries (LIC) and regions such as Sub-Saharan Africa (SSA) and Central and Eastern Europe (ECA). FDI flows from other groups such as East Asia and Pacific (EAP), the Latin American Integration Association (LAIA), and NAFTA also tend to positively impact the environmental performance of their partner countries.

However, results also show that FDI flows from upper-middle-income countries (UMC) tend to have negative and significant effects on the environmental performance of their partners, particularly high-income countries (HIC), advanced economies (AE), APEC, and SADC. These negative impacts suggest that FDI inflows from UMC may sometimes exacerbate environmental issues in these regions, particularly due to potentially less stringent environmental regulations or more polluting industrial practices. This highlights the need for more rigorous FDI frameworks and better coordination of environmental policies between UMC and their partners to minimize negative externalities.

Among the host country groups of FDI flows, ASEAN and NAFTA stand out for their ability to attract investments that positively affect their environmental performance. It is also noteworthy that groups such as lower-middle-income countries (LMIC), low-income countries (LIC), and SAARC (South Asian Association for Regional Cooperation, or SA) also benefit from FDI flows that seem generally positive for their environmental performance. This observation is surprising, given that these groups consist primarily of developing and emerging countries, particularly in South Asia, a region often perceived as more environmentally vulnerable.

Conversely, groups like COMESA and SADC seem to attract FDI from partners whose investments negatively impact their environmental performance. This could be explained by weaker environmental regulations, a greater dependence on natural resource extraction, or investments concentrated in high-pollution industries that do not favor sustainable practices in these regions. These factors may limit the ability of these countries to improve their environmental performance despite FDI inflows.

Regarding foreign direct investment (FDI) stocks, it appears that rich or developed countries (North, HIC) do not show a correlation between high or low levels of FDI stocks and their satisfactory environmental performance. Moreover, in emerging countries (South, UMIC, EM, COMESA, LAIA, SADC), better environmental performance is associated with higher levels of FDI stocks. Conversely, in developing countries, FDI stocks tend to concentrate in countries displaying lower levels of environmental performance. These results suggest that the relationship between environmental performance and FDI stocks varies according to the level of development of the host countries.

The other groups appear to exhibit highly heterogeneous and mixed effects.

Intra- and Intergroup Effects of FDI Flows

When considering intra-group effects (e.g., North-to-North, South-to-South, LID-to-LID), no significant effects are observed, except for the group of lower-middle-income countries (LMIC). The results suggest that within this group, partners focus on environmentally favorable investments. However, the opposite trend is observed for FDI stocks. This indicates that, while FDI flows tend to positively impact environmental performance, FDI stocks are more concentrated in countries with lower environmental performance.

The inter-group effects (e.g., between regions) appear to be highly heterogeneous, showing a wide variation in outcomes depending on the regions involved.

5.5.5 Further Analysis: The Effect of FDI from the USA, EEA, and China

Some of the largest global economies, notably the USA, the European Economic Area (EEA), and China (CHK_HKG)¹¹, exert significant influence on the global economy. For a more detailed analysis, we compare how these economies influence the environmental performance of their partners through their FDI.

The results (Tables 5.A11 and 5.A12) indicate that the FDI flows coming from EEA has mixed effects on host countries, with positive impacts on small island economies (Other Economies) and the APEC, but significant negative effects on upper-middle-income countries (UMC), low-income countries (LIC), and the COMESA.

¹¹Although we present results for mainland China (including Hong Kong) and China without Hong Kong, we focus only on the results with Hong Kong included.

The USA FDI flows shows positive effects on environmental performance of high-income countries (HIC), OtherEco, and the APEC, but significant negative impacts on regions such as the Middle East and North Africa (MENA), Latin America (LAC), as well as their North American partners (NA). In contrast, FDI flows coming from China and Hong Kong exhibit significant positive effects on environmental performance of several groups of countries, particularly the UMC, Latin America (LAC), and the APEC, but a significant negative impact on Sub-Saharan Africa (SSA).

The FDI flows from these three major economies exhibit complex dynamics, with varied impacts on the environmental performance of their host countries. The effects differ based on the geographic and developmental characteristics of host country groups. FDI from both the EEA and the USA tends to negatively affect environmental performance in regions such as COMESA and MENA, while showing positive or mixed effects in “*Other Region*” group. Chinese FDI flows, however, generally have positive impacts on environmental performance across most regions, except in Sub-Saharan Africa, where significant negative effects are observed. FDI flows from the USA and the EEA demonstrate similar patterns, with positive effects on the environmental performance of small island economies (Other Economies) and APEC countries, while negatively impacting specific regions.

5.6 Conclusion

This study examined the impact of Foreign Direct Investment (FDI) flows and stocks on the environmental performance of host countries, accounting for regional differences and the level of development across 174 countries from 2001 to 2022. Our findings reveal that the influence of FDI on environmental outcomes is far from being uniform and largely depends on the characteristics of both home and host countries, including their development levels, membership in trade blocs, and geographical positions.

On the one hand, FDI stocks tend to have a generally positive impact on environmental performance, particularly in emerging markets such as those in ASEAN, Latin America, and parts of Sub-Saharan Africa (notably East and Southern Africa, including COMESA countries). This could be attributed to the long-run stability of

FDI stocks, and their use in more structured sectors integrated into local economies. On the other hand, FDI flows, while contributing to short-run economic benefits, are often linked with negative environmental impacts, especially in regions such as Sub-Saharan Africa (SSA) and the Middle East and North Africa (MENA).

The results also show that the FDI flows from EEA and the United States exhibit positive effects on the environmental performance of certain regions such as small island economies (OtherEco) and APEC, while having negative impacts on others like COMESA and MENA. In contrast, the FDI flows from China and Hong Kong mainly have a positive influence on environmental performance of their partners, particularly in Latin America, MENA and emerging market, but show significant negative effects on Sub-Saharan Africa. Overall, the FDI flows from these three major economies display complex dynamics, with varying effects on environmental performance depending on their host partners' geographical location and levels of development.

A key takeaway from this study is that FDI stocks tend to be associated with environmental improvements in emerging and developing countries, whereas FDI flows, despite providing short-run economic gains, are often correlated with negative environmental outcomes. This suggests that the environmental effects of FDI are closely linked to the stability, quantity and nature of these investments: FDI stocks, typically tied to long-run projects and better integrated into local economies, appear to be more conducive to sustainability.

These findings have important policy implications. They highlight that attracting FDI should not come at the expense of environmental standards. Host countries must strengthen their regulatory frameworks to maximize the benefits of FDI while minimizing its negative externalities. Moreover, it is crucial to promote FDI that not only stimulates economic growth but also encourages the transfer of clean technologies and the adoption of sustainable management practices.

For FDI source countries, particularly developed economies, this study underscores the importance of promoting responsible investments by incorporating stricter environmental criteria in foreign investment decisions. Adopting sustainable investment practices, supported by public policies, could help minimize the negative impacts of FDI on hosting countries particularly in term of environmental performance.

This study highlights the complex relationship between FDI and the environment and underscores the importance of public policies in directing FDI towards greener growth. Future research should explore the sectoral impacts of FDI, particularly in pollution-intensive industries, to better understand the environmental consequences of FDI in specific economic contexts.

Finally, this study opens up several avenues for future research. Analyzing the sectoral impacts of FDI, especially in pollution-intensive industries, could provide deeper insights into the specific dynamics of certain industries. Additionally, exploring how host countries' environmental policies influence FDI attractiveness remains a key question that deserves further investigation. Understanding how national institutional frameworks interact with FDI flows could offer valuable guidance for policymakers seeking sustainable growth.

APPENDIX

A Tables

Table 5.A2: Partner countries groups

	Partner Group	Country list
TEA (Trade Economic Area) or Trade blocs	ASEAN (10 countries)	Brunei Darussalam; Indonesia; Cambodia; Lao PDR; Myanmar; Malaysia; Philippines; Singapore; Thailand; Vietnam
	SAARC (8 countries)	Afghanistan; Bangladesh; Bhutan; India; Sri Lanka; Maldives; Nepal; Pakistan
	COMESA (22 countries)	Burundi; Congo, Dem. Rep.; Comoros; Djibouti; Egypt, Arab Rep.; Eritrea; Ethiopia; Kenya; Libya; Madagascar; Mauritius; Malawi; Rwanda; Sudan; Somalia; Eswatini; Swaziland; Seychelles; Tunisia; Uganda; Zambia; Zimbabwe
	EEA (30 countries)	Austria; Belgium; Bulgaria; Cyprus; Czech Republic; Germany; Denmark; Spain; Estonia; Finland; France; Greece; Croatia; Hungary; Ireland; Iceland; Italy; Liechtenstein; Lithuania; Luxembourg; Latvia; Malta; Netherlands; Norway; Poland; Portugal; Romania; Slovak Republic; Slovenia; Sweden
	APEC (21 countries)	Australia; Brunei Darussalam; Canada; Chile; China; Hong Kong SAR, China; Indonesia; Japan; Korea, Rep.; Mexico; Malaysia; New Zealand; Peru; Philippines; Papua New Guinea; Russian Federation; Singapore; Thailand; Taiwan, China; United States; Vietnam
	IORA (23 countries)	United Arab Emirates; Australia; Bangladesh; Comoros; France; Indonesia; India; Iran, Islamic Rep.; Kenya; Sri Lanka; Madagascar; Maldives; Mozambique; Mauritius; Malaysia; Oman; Singapore; Somalia; Seychelles; Thailand; Tanzania; Yemen, Rep.; South Africa
	NAFTA (3 countries)	Canada; Mexico; United States
	MERCOSUR (5 countries)	Argentina; Brazil; Paraguay; Uruguay; Venezuela, RB
	LAIA (13 countries)	Argentina; Bolivia; Brazil; Chile; Colombia; Cuba; Ecuador; Mexico; Panama; Peru; Paraguay; Uruguay; Venezuela, RB
	SADC (17 countries)	Angola; Botswana; Congo, Dem. Rep.; Comoros; Lesotho; Madagascar; Mozambique; Mauritius; Malawi; Namibia; Eswatini; Swaziland; Seychelles; Tanzania; South Africa; Zambia; Zimbabwe

Table 5.A2 continued from previous page

Class	Partner Group	Country list
Income level (World Bank Classification)	HIC (77 countries)	Aruba; United Arab Emirates; Argentina; Antigua and Barbuda; Australia; Austria; Belgium; Bahrain; Bahamas, The; Bermuda; Barbados; Brunei Darussalam; Canada; Switzerland; Chile; Curacao; Cayman Islands; Cyprus; Czech Republic; Germany; Denmark; Spain; Estonia; Finland; France; Faroe Islands; United Kingdom; Equatorial Guinea; Greece; Greenland; Guam; Hong Kong SAR, China; Croatia; Hungary; Isle of Man; Ireland; Iceland; Israel; Italy; Japan; St. Kitts and Nevis; Korea, Rep.; Kuwait; Liechtenstein; Lithuania; Luxembourg; Latvia; Macao SAR, China; Monaco; Malta; Northern Mariana Islands; New Caledonia; Netherlands; Norway; New Zealand; Oman; Poland; Puerto Rico; Portugal; French Polynesia; Qatar; Russian Federation; Saudi Arabia; Singapore; San Marino; Slovak Republic; Slovenia; Sweden; Sint Maarten (Dutch part); Seychelles; Turks and Caicos Islands; Trinidad and Tobago; Taiwan, China; Uruguay; United States; Venezuela, RB; Virgin Islands (U.S.)
	UMC (57 countries)	Angola; Albania; American Samoa; Azerbaijan; Bulgaria; Bosnia and Herzegovina; Belarus; Belize; Brazil; Botswana; China; Colombia; Costa Rica; Cuba; Dominica; Dominican Republic; Algeria; Ecuador; Fiji; Gabon; Grenada; Iran, Islamic Rep.; Iraq; Jamaica; Jordan; Kazakhstan; Lebanon; Libya; St. Lucia; Maldives; Mexico; Marshall Islands; North Macedonia; Macedonia, FYR; Montenegro; Mongolia; Mauritius; Malaysia; Namibia; Panama; Peru; Palau; Paraguay; West Bank and Gaza; Romania; Serbia and Montenegro; Serbia; Suriname; Thailand; Turkmenistan; Tonga; Tunisia; Turkey; Tuvalu; St. Vincent and the Grenadines; Kosovo; South Africa
	LMIC (50 countries)	Armenia; Bangladesh; Bolivia; Bhutan; Cote d'Ivoire; Cameroon; Congo, Rep.; Cabo Verde; Djibouti; Egypt, Arab Rep.; Micronesia, Fed. Sts.; Georgia; Ghana; Guatemala; Guyana; Honduras; Indonesia; India; Kenya; Kyrgyz Republic; Kiribati; Lao PDR; Sri Lanka; Lesotho; Morocco; Moldova; Myanmar; Mauritania; Nigeria; Nicaragua; Pakistan; Philippines; Papua New Guinea; Sudan; Senegal; Solomon Islands; El Salvador; Sao Tome and Principe; Eswatini; Swaziland; Syrian Arab Republic; Tajikistan; Timor-Leste; Ukraine; Uzbekistan; Vietnam; Vanuatu; Samoa; Yemen, Rep.; Zambia
	LIC (32 countries)	Afghanistan; Burundi; Benin; Burkina Faso; Central African Republic; Congo, Dem. Rep.; Comoros; Eritrea; Ethiopia; Guinea; Gambia, The; Guinea-Bissau; Haiti; Cambodia; Liberia; Madagascar; Mali; Mozambique; Malawi; Niger; Nepal; Korea, Dem. People's Rep.; Korea, Dem. People's Rep.; Rwanda; Sierra Leone; Somalia; South Sudan; Chad; Togo; Tanzania; Uganda; Zimbabwe

Table 5.A2 continued from previous page

Class	Partner Group	Country list
	Other (35 countries)	Anguilla; Andorra; Netherlands Antilles; Antarctica; French Southern Territories; Bonaire, Saint Eustatius and Saba; Bouvet Island; Cocos islands; Cook Islands; Christmas island; Falkland Islands (Malvinas); Other territories; Guernsey; Gibraltar; Guadeloupe; Guiana, French; Heard islands and Mc Donald Islands; British Indian Ocean Territory; Jersey; Montserrat; Martinique; Mayotte; Norfolk Island; Niue; Nauru; Pitcairn; Reunion; South Georgia & South Sandwich Islands; Saint Helena; Saint Pierre and Miquelon; Tokelau; US Minor Outlying islands; Holy See (Vatican City State); British Virgin Islands; Wallis and Futuna
OECD	North (35 countries)	Australia; Austria; Belgium; Canada; Switzerland; Chile; Colombia; Costa Rica; Germany; Denmark; Spain; Estonia; Finland; France; United Kingdom; Greece; Hungary; Ireland; Iceland; Israel; Italy; Japan; Lithuania; Luxembourg; Latvia; Mexico; Netherlands; Norway; New Zealand; Poland; Portugal; Slovenia; Sweden; Turkey; United States

Table 5.A2 continued from previous page

Class	Partner Group	Country list
	South (216 countries)	Aruba; Afghanistan; Angola; Anguilla; Albania; Andorra; Netherlands Antilles; United Arab Emirates; Argentina; Armenia; American Samoa; Antarctica; French Southern Territories; Antigua and Barbuda; Azerbaijan; Burundi; Benin; Bonaire, Saint Eustatius and Saba; Burkina Faso; Bangladesh; Bulgaria; Bahrain; Bahamas, The; Bosnia and Herzegovina; Belarus; Belize; Bermuda; Bolivia; Brazil; Barbados; Brunei Darussalam; Bhutan; Bouvet Island; Botswana; Central African Republic; Cocos islands; China; Cote d'Ivoire; Cameroon; Congo, Dem. Rep.; Congo, Rep.; Cook Islands; Comoros; Cabo Verde; Cuba; Curacao; Christmas island; Cayman Islands; Cyprus; Czech Republic; Djibouti; Dominica; Dominican Republic; Algeria; Ecuador; Egypt, Arab Rep.; Eritrea; Ethiopia; Fiji; Falkland Islands (Malvinas); Other territories; Faroe Islands; Micronesia, Fed. Sts.; Gabon; Georgia; Guernsey; Ghana; Gibraltar; Guinea; Guadeloupe; Gambia, The; Guinea-Bissau; Equatorial Guinea; Grenada; Greenland; Guatemala; Guiana, French; Guam; Guyana; Hong Kong SAR, China; Heard islands and Mc Donald Islands; Honduras; Croatia; Haiti; Indonesia; Isle of Man; India; British Indian Ocean Territory; Iran, Islamic Rep.; Iraq; Jamaica; Jersey; Jordan; Kazakhstan; Kenya; Kyrgyz Republic; Cambodia; Kiribati; St. Kitts and Nevis; Korea, Rep.; Kuwait; Lao PDR; Lebanon; Liberia; Libya; St. Lucia; Liechtenstein; Sri Lanka; Lesotho; Macao SAR, China; Morocco; Monaco; Moldova; Madagascar; Maldives; Marshall Islands; North Macedonia; Macedonia, FYR; Mali; Malta; Myanmar; Montenegro; Mongolia; Northern Mariana Islands; Mozambique; Mauritania; Montserrat; Martinique; Mauritius; Malawi; Malaysia; Mayotte; Namibia; New Caledonia; Niger; Norfolk Island; Nigeria; Nicaragua; Niue; Nepal; Nauru; Oman; Pakistan; Panama; Pitcairn; Peru; Philippines; Palau; Papua New Guinea; Puerto Rico; Korea, Dem. People's Rep.; Korea, Dem. People's Rep.; Paraguay; West Bank and Gaza; French Polynesia; Qatar; Reunion; Romania; Russian Federation; Rwanda; Saudi Arabia; Serbia and Montenegro; Sudan; Senegal; Singapore; South Georgia & South Sandwich Islands; Saint Helena; Solomon Islands; Sierra Leone; El Salvador; San Marino; Somalia; Saint Pierre and Miquelon; Serbia; South Sudan; Sao Tome and Principe; Suriname; Slovak Republic; Eswatini; Swaziland; Sint Maarten (Dutch part); Seychelles; Syrian Arab Republic; Turks and Caicos Islands; Chad; Togo; Thailand; Tajikistan; Tokelau; Turkmenistan; Timor-Leste; Tonga; Trinidad and Tobago; Tunisia; Tuvalu; Taiwan, China; Tanzania; Uganda; Ukraine; US Minor Outlying islands; Uruguay; Uzbekistan; Holy See (Vatican City State); St. Vincent and the Grenadines; Venezuela, RB; British Virgin Islands; Virgin Islands (U.S.); Vietnam; Vanuatu; Wallis and Futuna; Samoa; Kosovo; Yemen, Rep.; South Africa; Zambia; Zimbabwe

Table 5.A2 continued from previous page

Class	Partner Group	Country list
Region (World Bank geographical classification)	LAC (40 countries)	Aruba; Argentina; Antigua and Barbuda; Bahamas, The; Belize; Bolivia; Brazil; Barbados; Chile; Colombia; Costa Rica; Cuba; Curacao; Cayman Islands; Dominica; Dominican Republic; Ecuador; Grenada; Guatemala; Guyana; Honduras; Haiti; Jamaica; St. Kitts and Nevis; St. Lucia; Mexico; Nicaragua; Panama; Peru; Puerto Rico; Paraguay; El Salvador; Suriname; Sint Maarten (Dutch part); Turks and Caicos Islands; Trinidad and Tobago; Uruguay; St. Vincent and the Grenadines; Venezuela, RB; Virgin Islands (U.S.)
	SA (8 countries)	Afghanistan; Bangladesh; Bhutan; India; Sri Lanka; Maldives; Nepal; Pakistan
	SSA (49 countries)	Angola; Burundi; Benin; Burkina Faso; Botswana; Central African Republic; Cote d'Ivoire; Cameroon; Congo, Dem. Rep.; Congo, Rep.; Comoros; Cabo Verde; Eritrea; Ethiopia; Gabon; Ghana; Guinea; Gambia, The; Guinea-Bissau; Equatorial Guinea; Kenya; Liberia; Lesotho; Madagascar; Mali; Mozambique; Mauritania; Mauritius; Malawi; Namibia; Niger; Nigeria; Rwanda; Sudan; Senegal; Sierra Leone; Somalia; South Sudan; Sao Tome and Principe; Eswatini; Swaziland; Seychelles; Chad; Togo; Tanzania; Uganda; South Africa; Zambia; Zimbabwe
	ECA (57 countries)	Albania; Armenia; Austria; Azerbaijan; Belgium; Bulgaria; Bosnia and Herzegovina; Belarus; Switzerland; Cyprus; Czech Republic; Germany; Denmark; Spain; Estonia; Finland; France; Faroe Islands; United Kingdom; Georgia; Greece; Greenland; Croatia; Hungary; Isle of Man; Ireland; Iceland; Italy; Kazakhstan; Kyrgyz Republic; Liechtenstein; Lithuania; Luxembourg; Latvia; Monaco; Moldova; North Macedonia; Macedonia, FYR; Montenegro; Netherlands; Norway; Poland; Portugal; Romania; Russian Federation; Serbia and Montenegro; San Marino; Serbia; Slovak Republic; Slovenia; Sweden; Tajikistan; Turkmenistan; Turkey; Ukraine; Uzbekistan; Kosovo
	MENA (21 countries)	United Arab Emirates; Bahrain; Djibouti; Algeria; Egypt, Arab Rep.; Iran, Islamic Rep.; Iraq; Israel; Jordan; Kuwait; Lebanon; Libya; Morocco; Malta; Oman; West Bank and Gaza; Qatar; Saudi Arabia; Syrian Arab Republic; Tunisia; Yemen, Rep.
	EAP (38 countries)	American Samoa; Australia; Brunei Darussalam; China; Fiji; Micronesia, Fed. Sts.; Guam; Hong Kong SAR, China; Indonesia; Japan; Cambodia; Kiribati; Korea, Rep.; Lao PDR; Macao SAR, China; Marshall Islands; Myanmar; Mongolia; Northern Mariana Islands; Malaysia; New Caledonia; New Zealand; Philippines; Palau; Papua New Guinea; Korea, Dem. People's Rep.; Korea, Dem. People's Rep.; French Polynesia; Singapore; Solomon Islands; Thailand; Timor-Leste; Tonga; Tuvalu; Taiwan, China; Vietnam; Vanuatu; Samoa
	NA (3 countries)	Bermuda; Canada; United States

Table 5.A2 continued from previous page

Class	Partner Group	Country list
Economies (Market Type or Income level from IFM classification)	Other (35 countries)	Anguilla; Andorra; Netherlands Antilles; Antarctica; French Southern Territories; Bonaire, Saint Eustatius and Saba; Bouvet Island; Cocos islands; Cook Islands; Christmas island; Falkland Islands (Malvinas); Other territories; Guernsey; Gibraltar; Guadeloupe; Guiana, French; Heard islands and Mc Donald Islands; British Indian Ocean Territory; Jersey; Montserrat; Martinique; Mayotte; Norfolk Island; Niue; Nauru; Pitcairn; Reunion; South Georgia & South Sandwich Islands; Saint Helena; Saint Pierre and Miquelon; Tokelau; US Minor Outlying islands; Holy See (Vatican City State); British Virgin Islands; Wallis and Futuna
	AE (41 countries)	Andorra; Australia; Austria; Belgium; Canada; Switzerland; Cyprus; Czech Republic; Germany; Denmark; Spain; Estonia; Finland; France; United Kingdom; Greece; Hong Kong SAR, China; Croatia; Ireland; Iceland; Israel; Italy; Japan; Korea, Rep.; Lithuania; Luxembourg; Latvia; Macao SAR, China; Malta; Netherlands; Norway; New Zealand; Puerto Rico; Portugal; Singapore; San Marino; Slovak Republic; Slovenia; Sweden; Taiwan, China; United States
	EM (86 countries)	United Arab Emirates; Bulgaria; Bahamas, The; Bosnia and Herzegovina; Belarus; Belize; Bolivia; Brazil; Brunei Darussalam; Botswana; Chile; China; Colombia; Cabo Verde; Costa Rica; Dominica; Dominican Republic; Ecuador; Egypt, Arab Rep.; Fiji; Micronesia, Fed. Sts.; Gabon; Georgia; Equatorial Guinea; Grenada; Guatemala; Guyana; Hungary; Indonesia; India; Iran, Islamic Rep.; Iraq; Jamaica; Jordan; Kazakhstan; St. Kitts and Nevis; Kuwait; Lebanon; Libya; St. Lucia; Sri Lanka; Morocco; Maldives; Mexico; Marshall Islands; North Macedonia; Macedonia, FYR; Montenegro; Mongolia; Mauritius; Malaysia; Namibia; Nauru; Oman; Pakistan; Panama; Peru; Philippines; Palau; Poland; Paraguay; Qatar; Romania; Russian Federation; Saudi Arabia; El Salvador; Serbia; Suriname; Eswatini; Swaziland; Seychelles; Thailand; Turkmenistan; Tonga; Trinidad and Tobago; Tunisia; Turkey; Tuvalu; Ukraine; Uruguay; St. Vincent and the Grenadines; Venezuela, RB; Vanuatu; Samoa; Kosovo; South Africa

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Class	Partner Group	Country list
	LID (59 countries)	Afghanistan; Burundi; Benin; Burkina Faso; Bangladesh; Bhutan; Central African Republic; Cote d'Ivoire; Cameroon; Congo, Dem. Rep.; Congo, Rep.; Comoros; Djibouti; Eritrea; Ethiopia; Ghana; Guinea; Gambia, The; Guinea-Bissau; Honduras; Haiti; Kenya; Kyrgyz Republic; Cambodia; Kiribati; Lao PDR; Liberia; Lesotho; Moldova; Madagascar; Mali; Myanmar; Mozambique; Mauritania; Malawi; Niger; Nigeria; Nicaragua; Nepal; Papua New Guinea; Rwanda; Sudan; Senegal; Solomon Islands; Sierra Leone; Somalia; South Sudan; Sao Tome and Principe; Chad; Togo; Tajikistan; Timor-Leste; Tanzania; Uganda; Uzbekistan; Vietnam; Yemen, Rep.; Zambia; Zimbabwe
	Other (65 countries)	Aruba; Angola; Anguilla; Albania; Netherlands Antilles; Argentina; Armenia; American Samoa; Antarctica; French Southern Territories; Antigua and Barbuda; Azerbaijan; Bonaire, Saint Eustatius and Saba; Bahrain; Bermuda; Barbados; Bouvet Island; Cocos islands; Cook Islands; Cuba; Curacao; Christmas island; Cayman Islands; Algeria; Falkland Islands (Malvinas); Other territories; Faroe Islands; Guernsey; Gibraltar; Guadeloupe; Greenland; Guiana, French; Guam; Heard islands and Mc Donald Islands; Isle of Man; British Indian Ocean Territory; Jersey; Liechtenstein; Monaco; Northern Mariana Islands; Montserrat; Martinique; Mayotte; New Caledonia; Norfolk Island; Niue; Pitcairn; Korea, Dem. People's Rep.; Korea, Dem. People's Rep.; West Bank and Gaza; French Polynesia; Reunion; Serbia and Montenegro; South Georgia & South Sandwich Islands; Saint Helena; Saint Pierre and Miquelon; Sint Maarten (Dutch part); Syrian Arab Republic; Turks and Caicos Islands; Tokelau; US Minor Outlying islands; Holy See (Vatican City State); British Virgin Islands; Virgin Islands (U.S.); Wallis and Futuna

Table 5.A1: EPI indicators definition

	Type	Abbreviation	Variable
	PolicyObjective	ECO	Ecosystem Vitality
	<i>IssueCategory</i>	<i>BDH</i>	<i>Biodiversity & Habitat</i>
1	Indicator	TBN	Terrestrial biome protection (national weights)
2	Indicator	TBG	Terrestrial biome protection (global weights)
3	Indicator	MPA	Marine protected areas
4	Indicator	PAR	Protected Areas Representativeness Index
5	Indicator	BHV	Biodiversity Habitat Index
6	Indicator	SPI	Species Protection Index
7	Indicator	SHI	Species Habitat Index
	<i>IssueCategory</i>	<i>ECS</i>	<i>Ecosystem Services</i>
8	Indicator	TCL	Tree cover loss
9	Indicator	GRL	Grassland loss
10	Indicator	WTL	Wetland loss
	<i>IssueCategory</i>	<i>FSH</i>	<i>Fisheries</i>
11	Indicator	FSS	Fish Stock Status
12	Indicator	RMS	Marine Trophic Index
13	Indicator	FTD	Fish caught by trawling
	<i>IssueCategory</i>	<i>ACD</i>	<i>Acidification</i>
14	Indicator	SDA	Adjusted emissions growth rate for sulfur dioxide
15	Indicator	NXA	Adjusted emissions growth rate for nitrous oxides
	<i>IssueCategory</i>	<i>AGR</i>	<i>Agriculture</i>
16	Indicator	SPU	Sustainable Pesticide Use
17	Indicator	SNM	Sustainable Nitrogen Management Index
	<i>IssueCategory</i>	<i>WRS</i>	<i>Water Resources</i>
18	Indicator	WWT	Wastewater treatment
	PolicyObjective	HLT	Environmental Health
	<i>IssueCategory</i>	<i>AIR</i>	<i>Air Quality</i>
19	Indicator	PMD	PM2.5 exposure
20	Indicator	HAD	Household solid fuels
21	Indicator	OZD	Ozone exposure
22	Indicator	NOE	NOx exposure
23	Indicator	SOE	SO2 exposure
24	Indicator	COE	CO exposure
25	Indicator	VOE	VOC exposure
	<i>IssueCategory</i>	<i>H2O</i>	<i>Sanitation & Drinking Water</i>
26	Indicator	USD	Unsafe sanitation
27	Indicator	UWD	Unsafe drinking water
	<i>IssueCategory</i>	<i>HMT</i>	<i>Heavy Metals</i>
28	Indicator	PBD	Lead exposure
	<i>IssueCategory</i>	<i>WMG</i>	<i>Waste Management</i>
29	Indicator	MSW	Controlled solid waste
30	Indicator	REC	Recycling
31	Indicator	OCP	Ocean Plastics
	PolicyObjective	PCC	Climate Change Policy Objective
	<i>IssueCategory</i>	<i>CCH</i>	<i>Climate Change</i>
32	Indicator	CDA	Adjusted emissions growth rate for carbon dioxide
33	Indicator	CHA	Adjusted emissions growth rate for methane
34	Indicator	FGA	Adjusted emissions growth rate for F-gases
35	Indicator	NDA	Adjusted emissions growth rate for nitrous oxide
36	Indicator	BCA	Adjusted emissions growth rate for black carbon
37	Indicator	GHN	Projected GHG Emissions in 2050
38	Indicator	LCB	Growth rate in carbon dioxide emissions from land cover
39	Indicator	GIB	Greenhouse gas intensity growth rate
40	Indicator	GHP	Greenhouse gas emissions per capita

Indicators are nested in IssueCategory, which are nested in PolicyObjective, which are finally use to calculate the EPI. See [Wolf et al. \(2022\)](#) for more detail.

Table 5.A3: Descriptive Statistics

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Year				2001	2022
EPI	3,828	41.51	12.08	15.83	79.79
FDI Net inflow (Million)	3,599	8,773	36,651	-204,699	660,768
FDI Net stock (Million)	3,607	120,952	360,650	-4,632	4.496e+06
Urban population rate	3,828	58.94	23.49	8.461	100
Manufacturing	3,798	11.82	6.822	0.233	49.88
Renewable energy consumption (%)	3,648	30.15	28.16	0	98.34
GDP per capita (Log)	3,817	8.728	1.418	5.542	11.77

Table 5.A4: Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) EPI	1.000						
(2) FDI Net inflow (Million)	0.125	1.000					
(3) FDI Net stock (Million)	0.244	0.626	1.000				
(4) GDP per capita (Log)	0.626	0.262	0.383	1.000			
(5) Urban population rate	0.412	0.197	0.289	0.747	1.000		
(6) Manufacturing	-0.055	0.051	0.080	0.028	0.076	1.000	
(7) Renewable energy consumption (%)	-0.285	-0.162	-0.209	-0.662	-0.541	-0.039	1.000

Table 5.A.5: Relationship between EPI and FDI (Flows and Stocks)

Group	EPI					FDI Net inflow					Group	FDI Net stock					
	mean	sd	min	max	N	mean	sd	min	max	N		mean	sd	min	max	N	
OtherReg	62	2	58	64	22	NAFTA	102017	114994	-7294	481329	63	NA	1304243	1237041	172097	4496376	63
OtherInc	62	2	58	64	22	NA	95713	122808	-146287	481329	63	NAFTA	1251187	1272702	98391	4496376	63
EEA	57	7	40	80	616	APEC	35516	66018	-131201	481329	420	APEC	446692	778813	21	4496376	420
AE	55	9	21	80	836	AE	27957	69469	-204446	660768	797	AE	391884	618418	10	4496376	798
North	54	10	23	78	770	North	27090	68971	-204446	660768	735	North	380436	598574	922	4496376	735
ECA	52	12	23	79	968	HIC	19430	57446	-204699	660768	1272	HIC	279530	520513	-129	4496376	1273
NA	52	7	42	65	66	EEA	18017	58554	-204446	660768	588	EEA	244646	345114	922	2986656	588
HIC	51	12	21	80	1334	ECA	14565	51226	-204446	660768	919	ECA	216802	369451	2	2986656	919
OtherEco	45	14	21	79	330	EAP	13522	35230	-72723	212783	576	EAP	173502	453096	-27	3208217	579
NAFTA	44	7	28	52	66	ASEAN	10621	26740	-72723	206197	189	IORA	137126	238192	6	1422507	399
LAC	42	8	23	70	748	IORA	10408	25649	-204699	206197	396	ALL	120952	360650	-4632	4496376	3607
ALL	42	12	16	80	3828	ALL	8773	36651	-204699	660768	3599	ASEAN	120129	237865	21	1422507	189
LAIA	40	4	28	50	264	MERCOSUR	7871	15895	-32630	62543	84	MERCOSUR	109006	150514	857	526370	84
UMC	39	9	16	71	1100	LAIA	7380	12562	-32630	62543	250	LAIA	83516	127632	18	526370	250
APEC	39	11	16	62	440	UMC	5141	19106	-38712	164520	1031	OtherEco	83003	187091	0	1104051	301
EM	39	9	16	71	1694	EM	4762	17860	-204699	164520	1598	UMC	63959	263485	-27	3208217	1035
SADC	39	9	21	67	286	South	4072	18983	-204699	212783	2864	EM	58635	217761	-129	3208217	1608
South	38	11	16	80	3058	OtherEco	3983	17290	-146287	89240	301	South	54545	223869	-4632	3208217	2872
EAP	38	11	16	62	616	LAC	3950	10656	-32630	81889	704	LAC	49803	126131	-129	1104051	706
MERCOSUR	38	4	28	47	88	SAARC	3498	10122	-1664	66865	160	SAARC	26401	74825	-1194	436500	162
COMESA	38	7	23	67	308	SA	3498	10122	-1664	66865	160	SA	26401	74825	-1194	436500	162
IORA	35	11	16	67	418	LMIC	1659	5886	-21250	66865	844	MENA	20347	29807	0	340217	372
SSA	35	7	21	67	836	MENA	1371	11700	-204699	43587	373	SADC	19926	44169	0	252062	271
LMIC	35	8	16	61	902	SADC	1277	6187	-38712	48679	267	LMIC	15327	41497	-4632	436500	850
MENA	35	9	22	80	396	COMESA	899	5650	-38712	48679	286	COMESA	13441	39818	0	252062	290
LID	33	7	19	61	968	SSA	662	4245	-38712	48679	784	SSA	9414	28323	-4632	252062	785
ASEAN	33	8	19	62	198	LID	537	2482	-17693	43679	903	LID	4758	11103	-4632	99707	900
LIC	32	5	19	52	462	LIC	369	1403	-3069	23562	432	LIC	2794	5823	-1194	55882	428
SAARC	30	9	16	53	176	OtherInc	-26	325	-1328	343	20	OtherInc	528	525	10	1339	21
SA	30	9	16	53	176	OtherReg	-26	325	-1328	343	20	OtherReg	528	525	10	1339	21

Table 5.A6: Model Specification with FDI Inflows

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FDI Net inflow (Lag)	-0.013 [0.014]	-0.018 [0.014]	-0.012 [0.015]	-0.018 [0.014]	0.000032 [0.0040]	-0.0011 [0.0041]	0.0013 [0.0033]	-0.0011 [0.0036]	-0.0018 [0.0044]	-0.0026 [0.0044]	-0.00056 [0.0039]	-0.0029 [0.0041]
GDP per capita (Log, Lag)	7.43*** [0.67]	-7.78 [5.06]	7.38*** [0.67]	-8.69* [5.02]	0.11 [1.52]	-12.7 [10.1]	-6.19*** [1.82]	-21.8** [10.6]	2.98** [1.20]	-7.97 [7.74]	1.13 [1.18]	-19.3** [8.22]
GDP per capita (Log, Square, Lag)		0.88*** [0.29]		0.93*** [0.29]		0.76 [0.57]		0.92 [0.59]		0.61 [0.42]		1.16*** [0.44]
Urban population rate (Lag)	-0.051 [0.035]	0.39*** [0.13]	-0.055 [0.035]	0.39*** [0.13]	0.55*** [0.092]	0.15 [0.28]	0.12 [0.12]	0.20 [0.24]	0.34*** [0.067]	0.030 [0.21]	0.21*** [0.063]	0.055 [0.18]
Urban population rate (Square, Lag)		-0.0039*** [0.0012]		-0.0040*** [0.0012]		0.0038 [0.0023]		-0.00020 [0.0019]		0.0028* [0.0017]		0.0014 [0.0015]
Manufacturing (Lag)	-0.11 [0.089]	-0.089 [0.23]	-0.093 [0.090]	-0.053 [0.23]	-0.19* [0.11]	-0.65*** [0.22]	-0.042 [0.100]	-0.38* [0.20]	-0.17* [0.096]	-0.53** [0.21]	-0.047 [0.088]	-0.34* [0.18]
Manufacturing (Square, Lag)		-0.0021 [0.0067]		-0.0024 [0.0068]		0.014*** [0.0040]		0.0095** [0.0038]		0.011*** [0.0038]		0.0089** [0.0036]
Renewable energy consumption (% Lag)	0.095*** [0.025]	0.13* [0.074]	0.093*** [0.025]	0.11 [0.074]	0.33*** [0.055]	0.25** [0.13]	0.26*** [0.053]	0.097 [0.11]	0.26*** [0.044]	0.24** [0.11]	0.22*** [0.043]	0.10 [0.096]
Renewable energy consumption (% Square, Lag)		-0.00063 [0.00080]		-0.00047 [0.00080]		0.0032 [0.0011]		0.0018* [0.0011]		-0.00027 [0.00097]		0.00084 [0.00092]
Constant	-21.6*** [5.64]	32.6 [22.1]	-22.6*** [5.67]	35.2 [22.0]	0.81 [12.3]	66.6 [42.5]	77.2*** [18.4]	142*** [45.7]	-9.87 [9.27]	47.8 [33.7]	11.5 [9.70]	106*** [36.8]
Observations	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585	3,585
R-squared	0.446	0.475	0.457	0.487	0.174	0.201	0.285	0.304				
Year FE	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Country FE	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
AIC	25948.0	25762.8	25917.8	25722.0	20286.4	20177.7	19807.8	19718.8				
BIC	25985.1	25824.6	26078.6	25907.6	20317.3	20233.4	19962.4	19898.1				
RMSE	9.018	8.783	8.955	8.709	4.095	4.031	3.820	3.771	4.319	4.278	4.156	4.098
Number of id					174	174	174	174				
hausman Chi2												
hausman p												
Fisher Stat. Year			3.52	4.05								
Fisher p. Year			0.00	0.00								
Fisher Stat. Country			75.77	73.67								
Fisher p. Country			0.00	0.00								

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 5.A7: Model Specification with FDI stock

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS				FE				RE			
FDI net stock (Lag)	-0.000071 [0.0019]	-0.000081 [0.0020]	-0.00052 [0.0019]	-0.0014 [0.0020]	0.0035*** [0.0013]	0.0029** [0.0012]	0.0022* [0.0012]	0.0018 [0.0012]	0.0036*** [0.0013]	0.0032** [0.0013]	0.0024** [0.0012]	0.0016 [0.0012]
GDP per capita (Log, Lag)	7.34*** [0.70]	-7.05 [5.34]	7.34*** [0.70]	-8.46 [5.33]	-0.60 [1.55]	-9.37 [10.2]	-6.53*** [1.80]	-19.6* [10.7]	2.32* [1.22]	-5.08 [7.66]	0.70 [1.21]	-17.4** [8.21]
GDP per capita (Log, Lag, Square)		0.84*** [0.31]		0.92*** [0.31]		0.53 [0.58]		0.77 [0.60]		0.42 [0.42]		1.04** [0.45]
Urban population rate (Lag)	-0.050 [0.035]	0.38*** [0.13]	-0.054 [0.035]	0.38*** [0.13]	0.52*** [0.092]	0.16 [0.29]	0.12 [0.11]	0.20 [0.24]	0.33*** [0.066]	0.034 [0.21]	0.21*** [0.064]	0.054 [0.19]
Urban population rate (Square, Lag)		-0.0039*** [0.0012]		-0.0040*** [0.0012]		0.0035 [0.0023]		-0.00024 [0.0019]		0.0027 [0.0017]		0.0015 [0.0015]
Manufacturing (Lag)	-0.12 [0.089]	-0.10 [0.23]	-0.095 [0.089]	-0.065 [0.23]	-0.18* [0.11]	-0.63*** [0.22]	-0.043 [0.100]	-0.38* [0.20]	-0.16* [0.096]	-0.52** [0.21]	-0.049 [0.088]	-0.34* [0.18]
Manufacturing (Square, Lag)		-0.0017 [0.0068]		-0.0020 [0.0068]		0.013*** [0.0040]		0.0095** [0.0038]		0.011*** [0.0038]		0.0089** [0.0037]
Renewable energy consumption (% ,Lag)	0.095*** [0.025]	0.14* [0.074]	0.093*** [0.025]	0.12 [0.074]	0.30*** [0.055]	0.22* [0.12]	0.25*** [0.053]	0.083 [0.11]	0.24*** [0.045]	0.21*** [0.10]	0.21*** [0.044]	0.092 [0.096]
Renewable energy consumption (% , Square, Lag)		-0.00066 [0.00080]		-0.00051 [0.00080]		0.00059 [0.0011]		0.0019* [0.0011]		0.000028 [0.000096]		0.00094 [0.00092]
Constant	-20.9*** [5.95]	29.7 [23.2]	-22.3*** [6.01]	34.2 [23.1]	8.79 [12.9]	55.8 [42.0]	80.5*** [17.9]	134*** [45.7]	-3.37 [9.58]	38.1 [33.1]	15.4 [9.97]	99.5*** [36.5]
Observations	3,593	3,593	3,593	3,593	3,593	3,593	3,593	3,593	3,593	3,593	3,593	3,593
R-squared	0.444	0.472	0.455	0.484	0.189	0.211	0.292	0.310	No	No	Yes	Yes
Year FE	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Country FE	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
AIC	26012.9	25835.7	25981.1	25790.5	20278.2	20186.1	19827.5	19744.8				
BIC	26050.1	25897.6	26142.0	25976.1	20309.2	20241.8	19982.1	19924.2				
RMSE	9.027	8.802	8.962	8.722	4.065	4.011	3.807	3.762	4.284	4.251	4.136	4.084
Number of id					174	174	174	174				
hausman Chi2												
hausman p												
Fisher Stat. Year			3.60	4.28								
Fisher p. Year			0.00	0.00								
Fisher Stat. Country			77.57	75.21								
Fisher p. Country			0.00	0.00								

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 5.A8: FDI Inflows impact on environmental performance

VARIABLES	(1)	(2) FE	(3)	(4)	(5) RE	(6)
FDI net stock (Lag)	0.0016 [0.0012]	0.0018 [0.0012]	0.0016 [0.0012]	0.0015 [0.0011]	0.0017 [0.0012]	0.0015 [0.0011]
GDP per capita (Log, Lag)	-22.7** [10.9]	-19.3* [10.2]	-23.8** [10.4]	-19.0** [8.29]	-19.8** [7.81]	-22.4*** [7.91]
GDP per capita (Log, Lag, Square)	0.95 [0.61]	0.76 [0.58]	1.01* [0.59]	1.13** [0.45]	1.16*** [0.42]	1.31*** [0.43]
Urban population rate (Lag)	0.091 [0.25]	0.17 [0.11]	0.17 [0.11]	0.0092 [0.19]	0.23*** [0.058]	0.23*** [0.059]
Urban population rate (Square, Lag)	0.00073 [0.0020]			0.0019 [0.0015]		
Manufacturing (Lag)	-0.34 [0.21]	-0.38* [0.20]	-0.34 [0.21]	-0.32* [0.19]	-0.35* [0.18]	-0.33* [0.19]
Manufacturing (Square, Lag)	0.0084** [0.0041]	0.0095** [0.0038]	0.0084** [0.0041]	0.0084** [0.0038]	0.0091** [0.0036]	0.0086** [0.0038]
Renewable energy consumption (% ,Lag)	0.22*** [0.061]	0.083 [0.11]	0.22*** [0.061]	0.16*** [0.049]	0.084 [0.096]	0.17*** [0.050]
Renewable energy consumption (% , Square, Lag)		0.0019* [0.0011]			0.0011 [0.00092]	
Constant	149*** [47.5]	134*** [44.4]	152*** [46.3]	107*** [37.2]	106*** [35.9]	117*** [36.7]
Observations	3,593	3,593	3,593	3,593	3,593	3,593
R-squared	0.304	0.310	0.304			
Number of id	174	174	174	174	174	174
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
AIC	19772.7	19742.9	19771.5			
BIC	19945.9	19916.1	19938.6			
RMSE	3.777	3.761	3.777	4.090	4.074	4.082
hausman Chi2				528.03	387.54	465.30
hausman p				0.00	0.00	0.00

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 5.A9: FDI stock impact on environmental performance

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
		FE			RE	
FDI net stock (Lag)	0.0016 [0.0012]	0.0018 [0.0012]	0.0016 [0.0012]	0.0015 [0.0011]	0.0017 [0.0012]	0.0015 [0.0011]
GDP per capita (Log, Lag)	-22.7** [10.9]	-19.3* [10.2]	-23.8** [10.4]	-19.0** [8.29]	-19.8** [7.81]	-22.4*** [7.91]
GDP per capita (Log, Lag, Square)	0.95 [0.61]	0.76 [0.58]	1.01* [0.59]	1.13** [0.45]	1.16*** [0.42]	1.31*** [0.43]
Urban population rate (Lag)	0.091 [0.25]	0.17 [0.11]	0.17 [0.11]	0.0092 [0.19]	0.23*** [0.058]	0.23*** [0.059]
Urban population rate (Square, Lag)	0.00073 [0.0020]			0.0019 [0.0015]		
Manufacturing (Lag)	-0.34 [0.21]	-0.38* [0.20]	-0.34 [0.21]	-0.32* [0.19]	-0.35* [0.18]	-0.33* [0.19]
Manufacturing (Square, Lag)	0.0084** [0.0041]	0.0095** [0.0038]	0.0084** [0.0041]	0.0084** [0.0038]	0.0091** [0.0036]	0.0086** [0.0038]
Renewable energy consumption (% , Lag)	0.22*** [0.061]	0.083 [0.11]	0.22*** [0.061]	0.16*** [0.049]	0.084 [0.096]	0.17*** [0.050]
Renewable energy consumption (% , Square, Lag)		0.0019* [0.0011]			0.0011 [0.00092]	
Constant	149*** [47.5]	134*** [44.4]	152*** [46.3]	107*** [37.2]	106*** [35.9]	117*** [36.7]
Observations	3,593	3,593	3,593	3,593	3,593	3,593
R-squared	0.304	0.310	0.304			
Number of id	174	174	174	174	174	174
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
AIC	19772.7	19742.9	19771.5			
BIC	19945.9	19916.1	19938.6			
RMSE	3.777	3.761	3.777	4.090	4.074	4.082
hausman Chi2				528.03	387.54	465.30
hausman p				0.00	0.00	0.00

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 5.A10: FDI Inflow and stock impact on environmental performance

VARIABLES	(1) FE	(2) FE	(3) FE	(4) FE
FDI net inflow (Lag),	-0.00098 [0.0041]	-0.00098 [0.0041]	-0.0013 [0.0050]	-0.0013 [0.0050]
FDI net stock (Lag)	0.0016 [0.0012]	0.0016 [0.0012]	0.0016 [0.0013]	0.0016 [0.0013]
FDI net inflow $\times$ FDI net stock (Lag)			2.3e-07 [3.0e-06]	2.3e-07 [3.0e-06]
GDP per capita (Log, Lag)	-23.8** [10.5]	-23.8** [10.5]	-23.8** [10.5]	-23.8** [10.5]
GDP per capita (Log, Lag, Square)	1.01* [0.59]	1.01* [0.59]	1.01* [0.59]	1.01* [0.59]
Urban population rate (Lag)	0.17 [0.11]	0.17 [0.11]	0.17 [0.11]	0.17 [0.11]
Manufacturing (Lag)	-0.32 [0.21]	-0.32 [0.21]	-0.33 [0.21]	-0.33 [0.21]
Manufacturing (Square, Lag)	0.0082** [0.0041]	0.0082** [0.0041]	0.0082** [0.0041]	0.0082** [0.0041]
Renewable energy consumption (% , Lag)	0.22*** [0.062]	0.22*** [0.062]	0.22*** [0.062]	0.22*** [0.062]
Constant	152*** [46.5]	152*** [46.5]	152*** [46.5]	152*** [46.5]
Observations	3,577	3,577	3,577	3,577
R-squared	0.302	0.302	0.302	0.302
Number of id	174	174	174	174
Year FE	No	Yes	No	Yes
Country FE	Yes	Yes	Yes	Yes
RMSE	3.780	3.780	3.781	3.781

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 5.A11: Heterogeneity and further analysis of FDI inflow

[illegible]

Further analysis

reporter in column, origine in row (direction: from row to column)

Table 5.A12: Heterogeneity and further analysis of FDI stock

	ALL	North	South	HIC	UMC	LMIC	LIC	AE	EAI	LID	OtherEco	EAP	ECA	LAC	MEXA	NA	SA	SSA	AFPC	ASEAN	COMESA	EEA	IOFA	LAIA	MERCOSUR	NAFTA	SAMIC	SADC	
ALL	0.0016	0.0026	0.0018	-0.0029	0.0045***	0.0015	-0.0009	-0.0012	0.0043***	-0.0031	-0.0032	0.0012	0.00032	0.010	0.034**	0.0013	0.0011	0.031	0.00040	0.0001	0.043**	-0.0019	-0.0047	0.013***	0.0076	0.0074	0.014	0.013	
North	0.0012	0.0028	-0.0008	-0.0019	0.013*	0.041*	-0.18	-0.0024	0.015**	0.0036	-0.022	0.016**	-0.0074	0.085	0.037**	0.0016	0.031	0.026	0.00010	0.022	0.21**	-0.0026*	-0.00053	0.015***	0.0070	0.00077	0.031	0.063	
South	0.0028	-0.0008	0.0019	-0.0019	0.013*	0.041*	-0.12	-0.0073	0.0048*	-0.071	0.019**	0.0083	0.0039	0.025***	0.064	0.0019	0.025	0.045	-0.00080	0.014	0.04*	-0.00069	-0.012**	0.018	0.045	0.00045	0.025	0.044	
UMC	0.0019	-0.00014	0.00412*	-0.00023	0.0054***	0.0022	-0.0096	0.00023	0.0031***	-0.02	-0.017	0.0034	-0.00035	0.0089	0.035**	0.0014	0.022	0.026	0.00016	0.013	0.080**	-0.0022	-0.0027	0.013***	0.0081	0.00071	0.022	0.040**	
HIC	-0.00021	-0.00028	0.00028	-0.00028	0.0031	0.050*	-0.21	-0.0035	0.0036**	-0.035	0.029***	-0.00033	-0.0012	0.034***	0.28*	0.018	0.033	0.004	-0.00011***	0.053	0.18	-0.034	-0.0021	0.011*	0.078	-0.015	0.033	-0.028	
LMIC	-0.018	0.015	-0.012	-0.012	0.023**	0.069**	-0.47	0.0034	0.0036	-0.035	0.029***	0.0028	-0.0016	0.025***	0.16*	0.018	0.033	0.004	0.033**	-0.013	0.33*	-0.0023	0.012	0.044	0.08	0.018	0.038	0.028	
LIC	0.0045	0.020	-0.0073	0.0034	0.055***	-0.71**	-4.12**	0.0043	0.046**	-0.56**	-1.33	0.0021*	0.021*	0.049	-0.087	-1.57	0.36	0.00045	-0.00045	-0.028	0.64**	0.0073*	-0.0027	-0.0016	0.14*	0.0097	1.57	1.08**	
OtherEco	0.0080	0.020	-0.0073	0.0034	0.055***	-0.71**	-4.12**	0.0043	0.046**	-0.56**	-1.33	0.0021*	0.021*	0.049	-0.087	-1.57	0.36	0.00045	-0.00045	-0.028	0.64**	0.0073*	-0.0027	-0.0016	0.14*	0.0097	1.57	1.08**	
AE	0.0020	-0.00040	0.0049***	-0.0011	0.0050***	0.027**	0.004	-0.0032	0.0054**	0.035	-0.017	0.0037	-0.0003	0.011	0.038*	0.0018	0.076	0.036	0.00063	0.024	0.12*	-0.035	-0.010	0.055*	0.0057	-0.0077	0.052	0.065	
EAI	0.0050	-0.0012	0.0024	-0.0027	0.004*	0.013	-0.18*	-0.0037	0.0058**	-0.068	0.026**	-0.00025	-0.00089	0.031**	0.052	-0.020	0.033	0.086	-0.00102	0.036	0.12*	-0.011	-0.032*	0.028	0.022	-0.0022	0.033	0.021	
LMC	0.0035	0.0080	-0.0025	0.0023	0.036**	-2.48*	0.26	0.0027	0.024***	-0.22**	0.11	-0.0057	0.0093*	0.015	-0.40	-0.035	0.27	0.078	-0.024	0.019	0.12**	0.0021	-0.027	0.043	0.115	0.0097	0.27	0.23**	
OtherEco	0.0080	0.020	-0.0073	0.0034	0.055***	-0.71**	-4.12**	0.0043	0.046**	-0.56**	-1.33	0.0021*	0.021*	0.049	-0.087	-1.57	0.36	0.00045	-0.00045	-0.028	0.64**	0.0073*	-0.0027	-0.0016	0.14*	0.0097	1.57	1.08**	
EAP	0.0035	-0.0031	0.0029	-0.0034	0.0067***	0.037*	0.34	-0.0030*	0.0056***	0.12*	0.022**	0.0016	0.016	0.027***	0.40	-0.026	0.052	0.19***	0.00063	0.024	0.12*	-0.035	-0.010	0.055*	0.0057	-0.0077	0.052	0.065	
ECA	0.0010	-0.0001	0.0037	-0.0001	0.0020	0.024	-0.54	-0.00098	0.0015	-0.31**	-0.038	0.013	-0.0026	0.013	0.041**	-0.0026	0.054	0.062	0.00047	0.012	0.27**	-0.0040	-0.001	0.021**	0.0011	-0.0077	0.052	0.065	
LAC	0.0013	0.0031	0.0035	-0.0011	0.0088**	-0.32	0.19*	-0.0027	0.0095***	-0.14	0.19*	0.0028	0.014	0.53**	0.12	-0.089	0.94	0.23***	-0.0087	0.000	0.12**	-0.061	-0.033*	0.036	0.017	-0.0030	0.30	0.17	
MEXA	0.0003	0.0006	0.0006	0.0006	0.0036**	0.10**	-0.06	0.0004	0.0031**	-0.02	-0.020	0.0029*	0.0070	0.020	0.0011	0.076	0.12	0.079	0.0080	0.065**	0.18*	-0.007	-0.016	0.028**	0.051*	-0.00026	0.12	0.40**	
NA	0.0051	0.0053	0.0012	0.0004	0.039**	0.059	0.10**	0.0040	0.033**	-0.23*	-0.020	0.014	0.44	0.59	0.77***	0.29*	0.40	0.25	-0.018	0.038	0.18*	-0.20*	-0.16	0.86	2.93	0.24	-0.40	0.44**	
SA	0.0	0.0	-0.011	0.030	0.18**	-0.51**	-1.67**	-0.0048	0.24***	-0.41	-0.52	-0.14	0.44	0.59	0.77***	0.29*	0.40	0.25	-0.018	0.038	0.18*	-0.20*	-0.16	0.86	2.93	0.24	-0.40	0.44**	
SSA	-0.0051	-0.0051	-0.024	-0.024	0.055*	-0.22**	-0.15**	0.033*	-0.0012	0.020	0.033*	-0.001*	-0.021	0.99**	0.35**	-0.25	0.10	0.013	-0.038	0.052	0.17	-0.057	-0.018	-0.80	0.76***	-0.426	0.10*	-0.030	
OtherReg	0.0080	0.020	-0.0073	0.0043	0.055***	-0.71**	-4.12**	0.0043	0.046**	-0.56**	-1.33	-0.012	0.021	0.99**	0.35**	-0.25	0.10	0.013	-0.038	0.052	0.17	-0.057	-0.018	-0.80	0.76***	-0.426	0.10*	-0.030	
IOFA	0.0033	0.0014	0.0030	-0.0024	0.0060***	0.038**	0.21	-0.0070	0.0048***	0.11**	0.030	0.0020	0.0053	0.016**	0.080	0.097	0.038	0.11**	0.000	0.091	0.13*	-0.001	-0.008	0.038***	0.030*	0.003	0.009	0.009	
LAIA	0.0034	0.0005	0.0016	-0.015	0.11**	0.050	1.07**	-0.012	0.081**	0.069**	0.46*	0.026	0.062	0.12	0.26	0.30	0.14**	0.14**	0.0033	0.057	0.065	-0.005	-0.012	-0.007	0.093	0.15**	0.14**	0.16	
ASEAN	0.024	0.0005	0.006	-0.015	0.11**	0.050	1.07**	-0.012	0.081**	0.069**	0.46*	0.026	0.062	0.12	0.26	0.30	0.14**	0.14**	0.0033	0.057	0.065	-0.005	-0.012	-0.007	0.093	0.15**	0.14**	0.16	
COMESA	0.0046	0.006	-0.0050	-0.018	0.22**	0.025	-0.13**	-0.012	0.0915	-0.082*	1.00**	0.013	-0.0026	0.017	0.034***	-0.04	0.018	-0.031	0.0083	0.078	0.067	-0.032	-0.005	3.00*	-2.64	-0.0023	0.018	-0.050	
EEA	0.0017	-0.0013	0.015	-0.0015	0.0025*	0.065	-0.78	-0.0015	0.018*	-0.27**	-0.036	0.018	-0.0026	0.017	0.044***	-0.0062	0.077	0.100	0.00037	0.021	0.38***	-0.003	0.014	0.027**	0.011	-0.00050	0.077	0.086	
IOFA	0.0082	-0.015*	0.017	-0.018**	0.0659***	0.025	-0.10*	-0.019**	0.045**	-0.10*	-0.096	0.018	-0.021**	0.033	0.075	-0.0028	0.065	0.020	0.0024	0.035	0.082*	-0.035	-0.022	0.045	0.12*	0.0096	0.020	0.017	
LAIA	0.0042	0.0012	0.089***	0.040	-0.052	-0.40	1.20***	-0.00077	0.060	0.70**	0.84	-0.22	0.023	0.056	0.0098	-0.0028	0.136	0.27	0.017	-0.34	13.2**	-0.025	-0.79	0.912	0.0061	-0.11**	13.6	-0.36	
MERCOSUR	0.066*	0.001	0.18***	0.045	0.18	-0.65***	1.06***	-0.0074	0.16***	0.84	0.22**	2.86	0.057	0.045	-0.42	-0.024	-0.70	-0.12	0.16	0.39	15.8*	-0.021	0.41	0.33*	0.56	-0.014	2.65	-0.66	
NAFTA	0.0060	0.0030	0.017	0.0030	0.025*	0.16**	0.12	0.0048	0.033**	0.11	-0.019	0.034**	0.0071	0.023	0.092	0.010	0.12	0.35	0.010	0.063**	0.18*	-0.023	-0.017	0.029**	0.036*	0.00076	0.12	0.49**	
SAMIC	0.006	0.00	-0.011	0.030	0.12**	-0.51**	-1.67**	-0.0048	0.24***	-0.41	-0.52	-0.14	0.44	0.59	0.77***	0.29*	0.40	0.25	-0.018	0.038	0.18*	-0.20*	-0.16	0.86	2.93	0.24	-0.40	0.44**	
SADC	0.0004	-0.0001	0.021	-0.023	0.21**	0.062**	-0.22**	-0.013	0.049	-0.13*	1.32***	-0.089*	-0.020*	0.99**	0.34*	-0.38	0.11*	0.011	-0.049	0.089	0.18	-0.043	-0.030	-0.78	0.77**	0.21	-0.01	0.080	
Further analysis																													
USA	0.0063	0.0026	0.017	0.0027	0.027*	0.21**	-0.14	0.0063	0.069	0.074	-0.017	0.030**	0.0075	0.035	0.12	0.021	0.13	0.30	0.022**	0.660**	0.50	-0.0027	-0.019*	0.030**	0.007**	0.085	0.13	0.52*	
CHN	-0.0050	-0.025	-0.0082	-0.0025	0.0072***	0.16	0.61	-0.0036	-0.0034**	0.11	0.12	0.033***	-0.0036	0.036***	0.79*	0.12*	0.35	0.50	-0.0040***	-0.20	-0.023	0.054	0.32	-0.16	0.35	-0.25	-0.24	-0.24	
HKG	0.0033	-0.048*	0.0027	-0.0025	0.0072***	0.15	0.66	0.0012	-0.0038	0.033***	0.85*	0.046*	0.0012	0.038	0.85*	0.046*	0.35	0.52*	0.00061	0.092	0.37*	-0.084	-0.11	-0.091	-0.12	0.32	0.13	0.13	
EEA	0.0017	-0.0013	0.015	-0.0015	0.025*	0.065	-0.78	-0.0015	0.018*	-0.27**	-0.034	0.013	-0.0026	0.017	0.044***	-0.0062	0.077	0.100	0.00833	0.021	0.38***	-0.003	0.014	0.027**	0.011	-0.00050	0.077	0.086	
Further in row (direction: from row to column)																													

B Figures

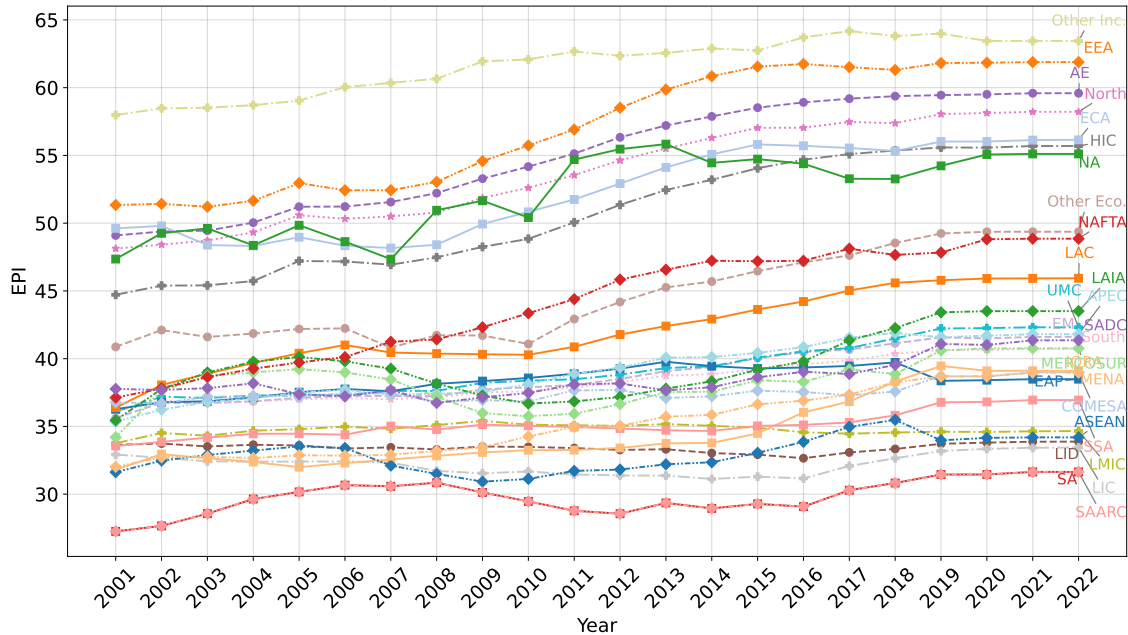


Figure 5.B1: EPI Evolution

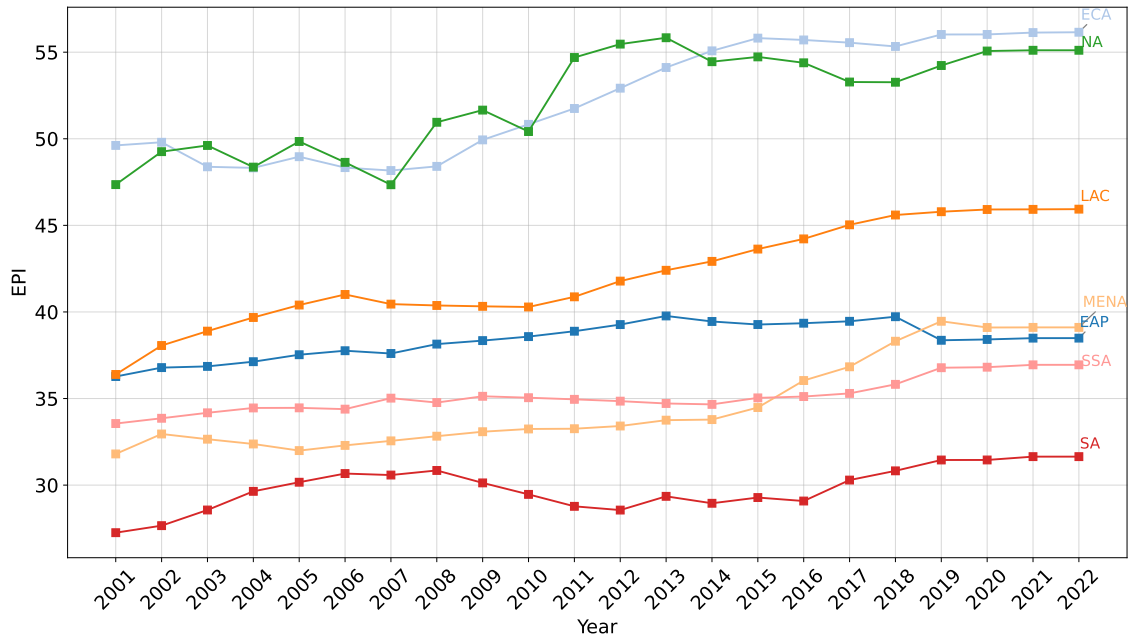


Figure 5.B2: EPI Evolution by region

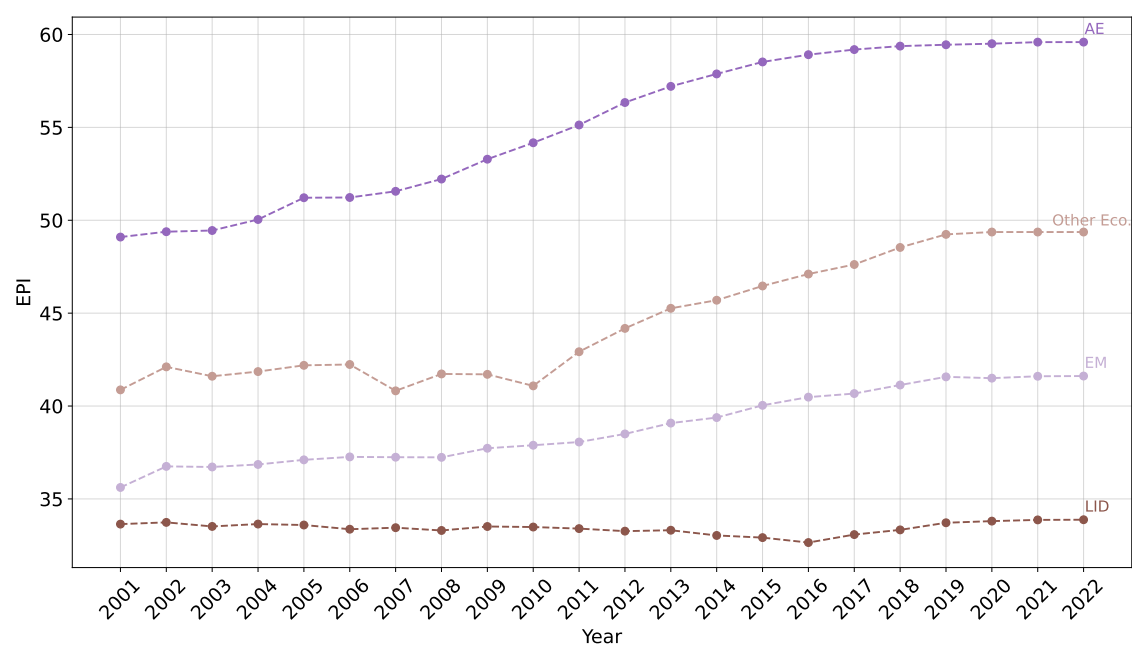


Figure 5.B3: EPI Evolution by type of economy

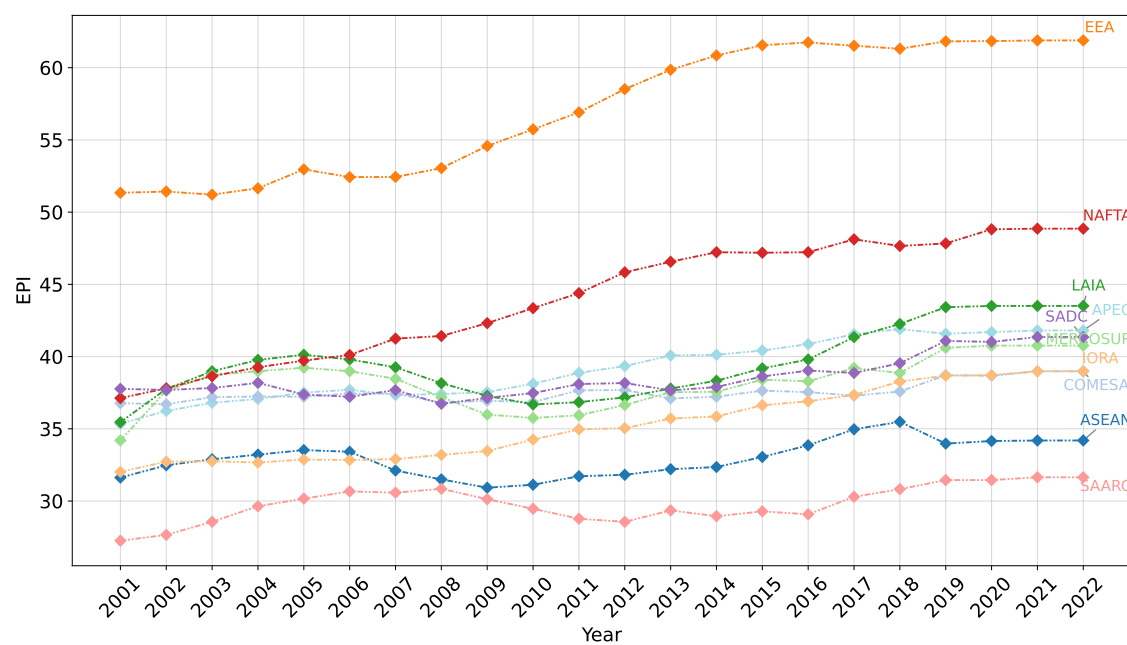


Figure 5.B4: EPI Evolution by type by Trade Economic Area (Trade Blocs)

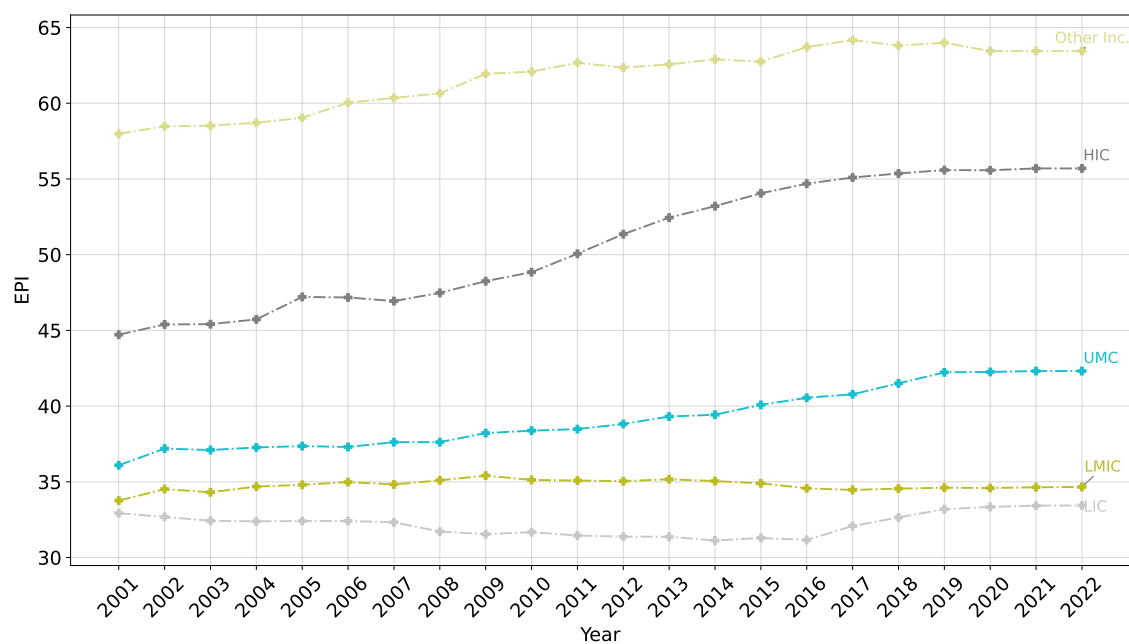


Figure 5.B5: EPI Evolution by income groups

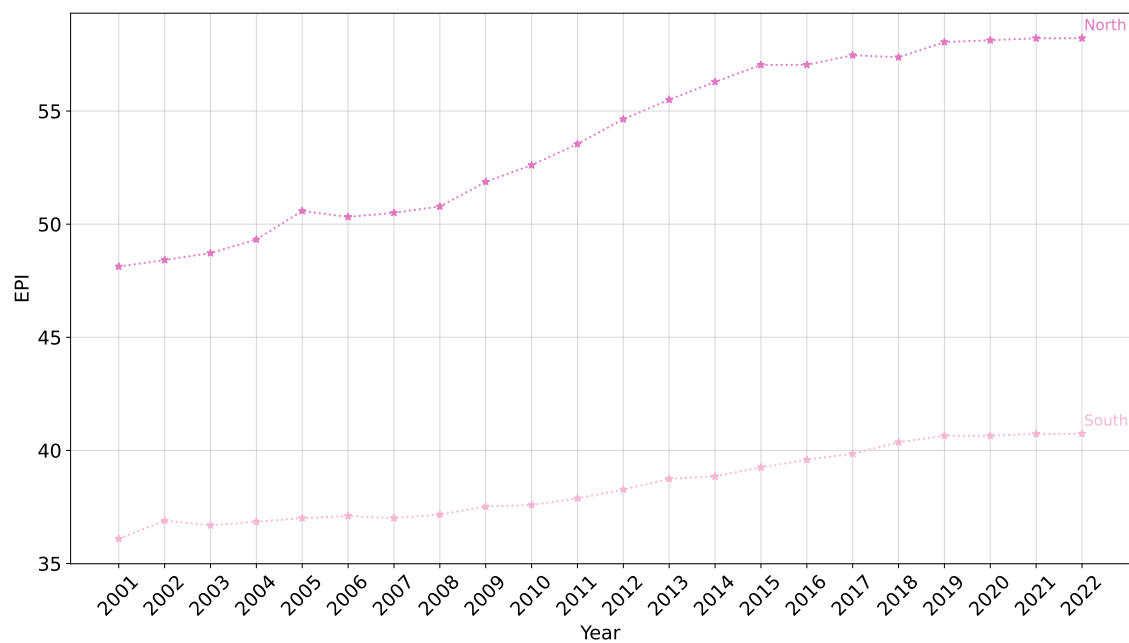
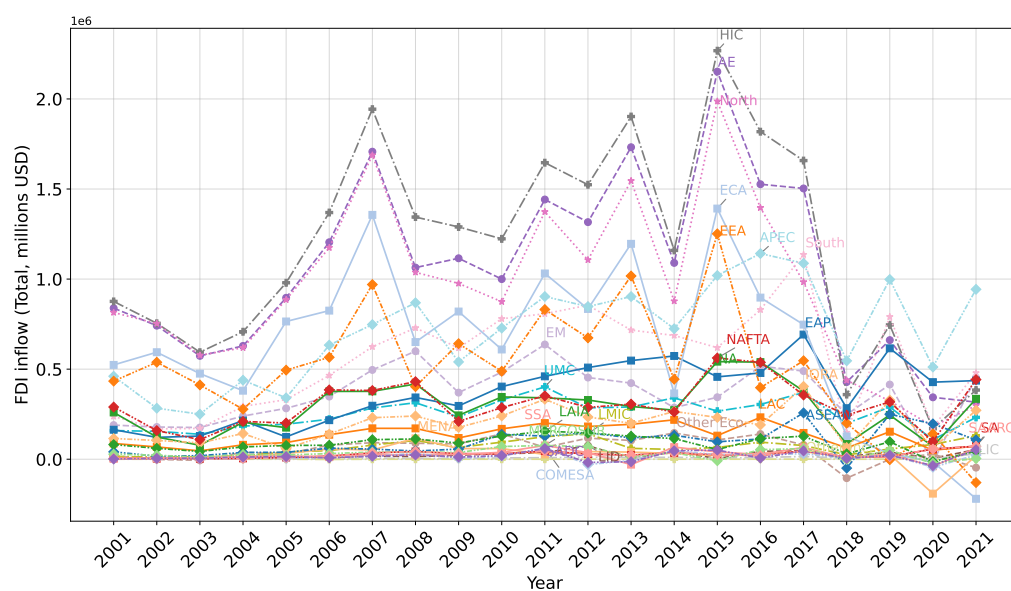
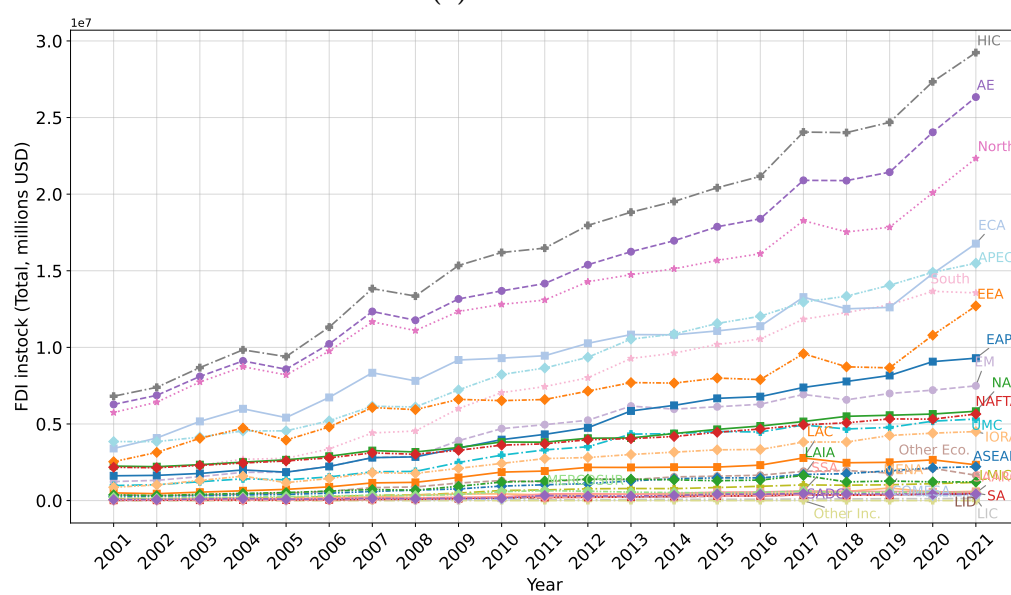


Figure 5.B6: EPI Evolution by geographic groups

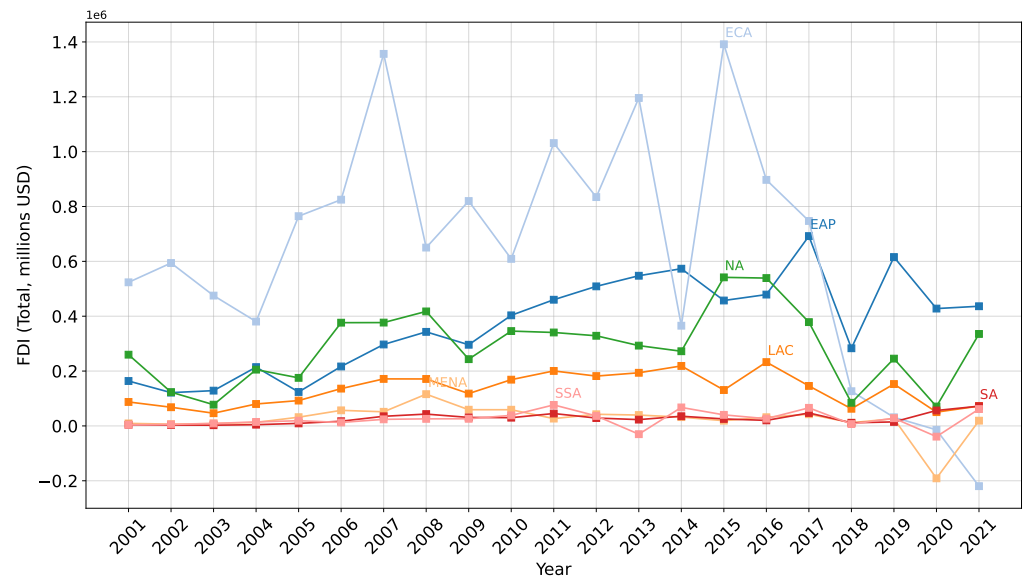


(a) FDI inflow

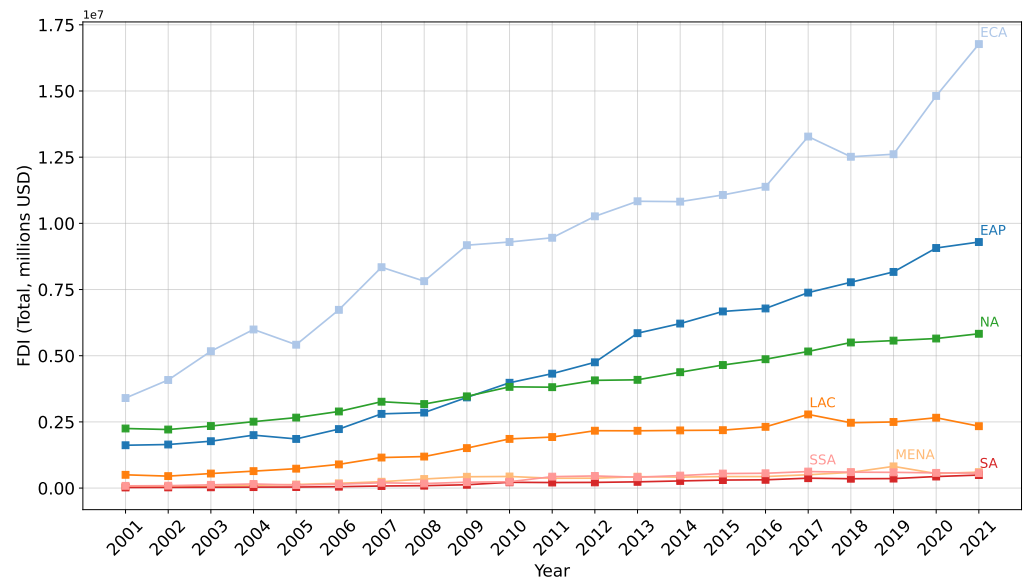


(b) FDI stock

Figure 5.B7: Total FDI Evolution

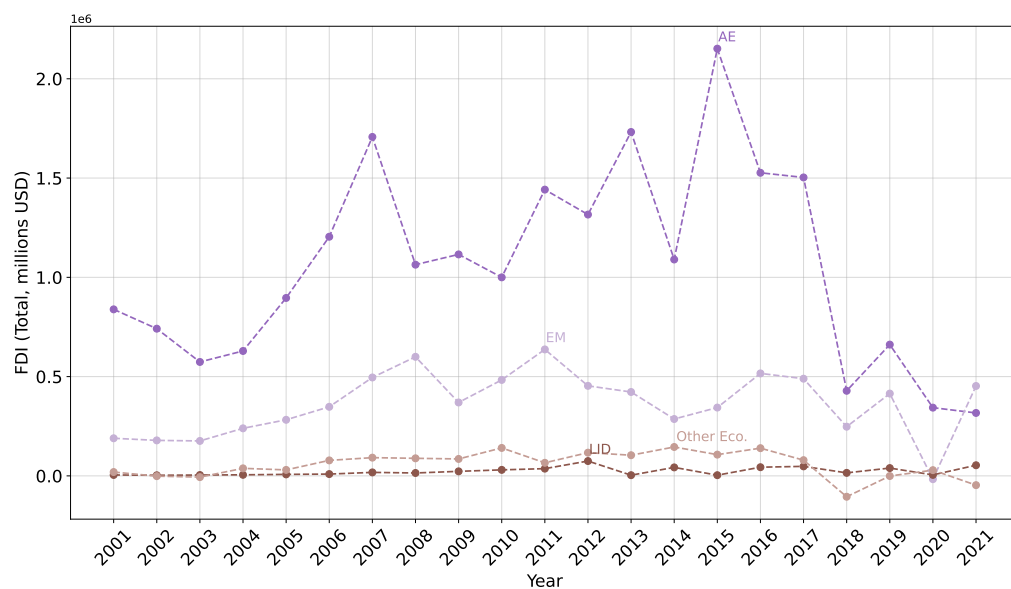


(a) FDI inflow

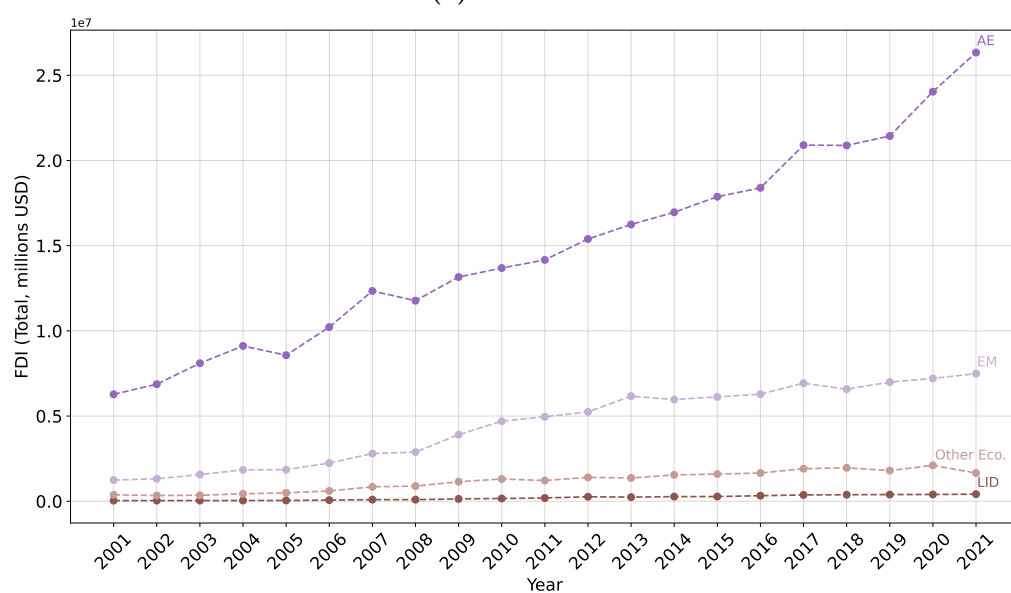


(b) FDI stock

Figure 5.B8: Total FDI Evolution by region

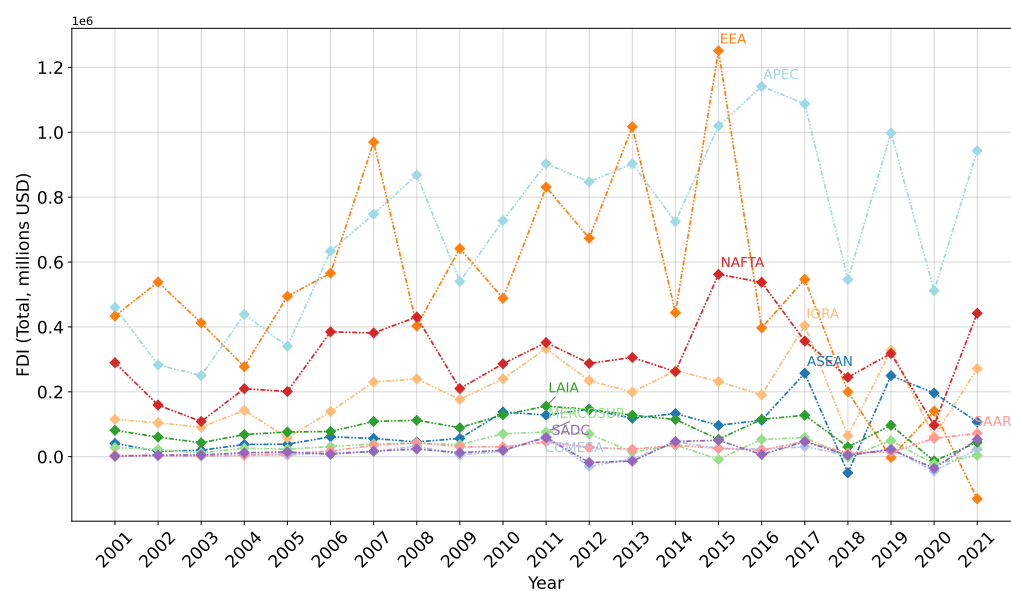


(a) FDI inflow

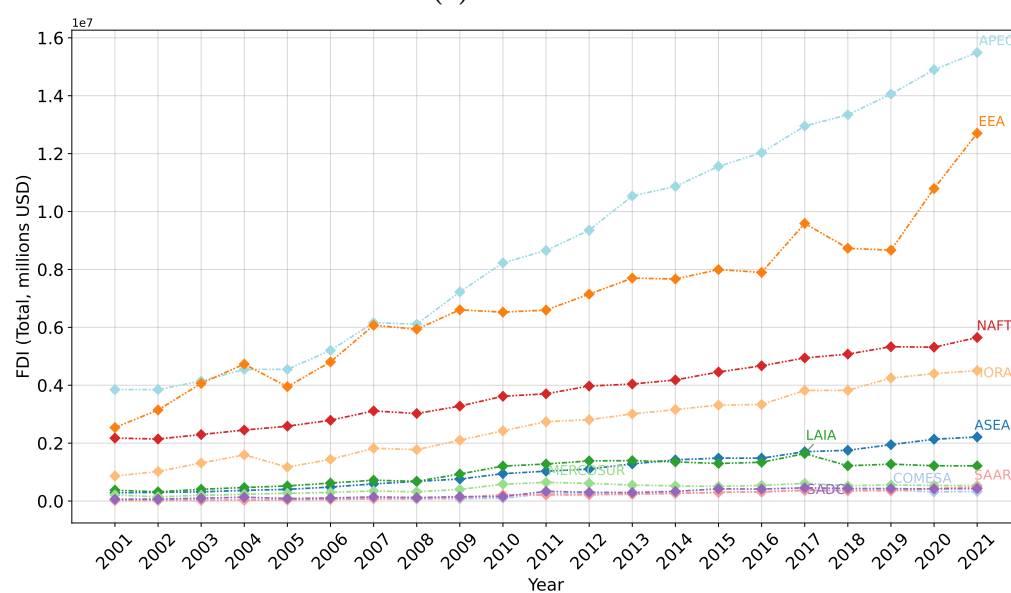


(b) FDI stock

Figure 5.B9: Total FDI Evolution by type of economy

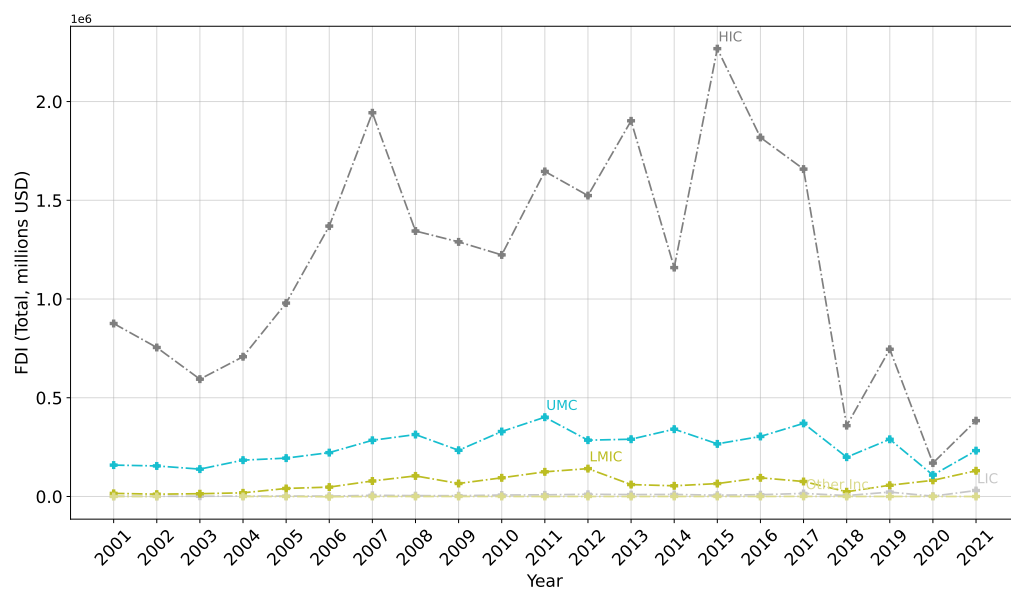


(a) FDI inflow

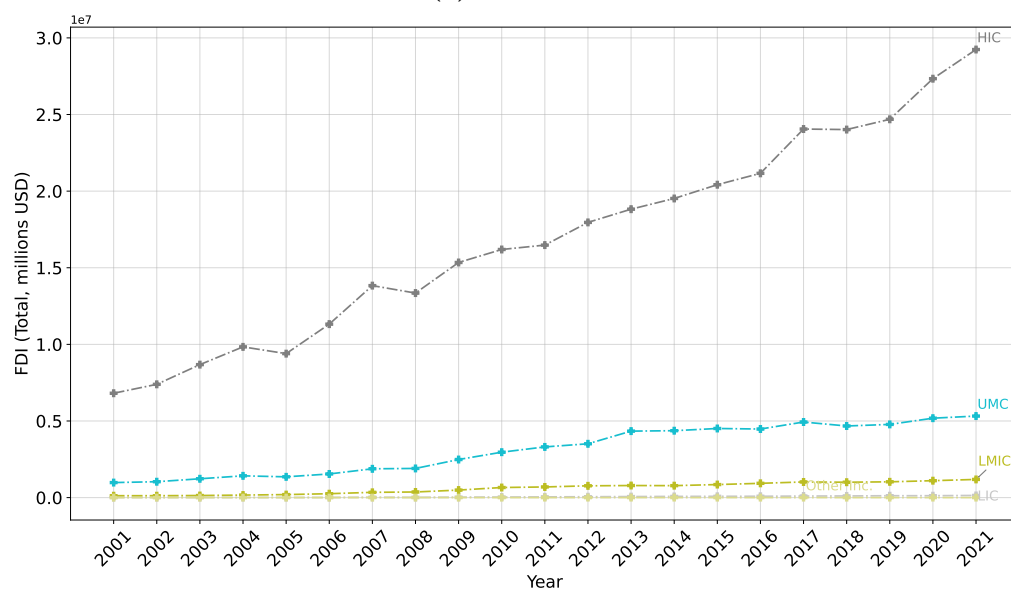


(b) FDI stock

Figure 5.B10: Total FDI Evolution by Trade Economic Area (Trade Blocs)

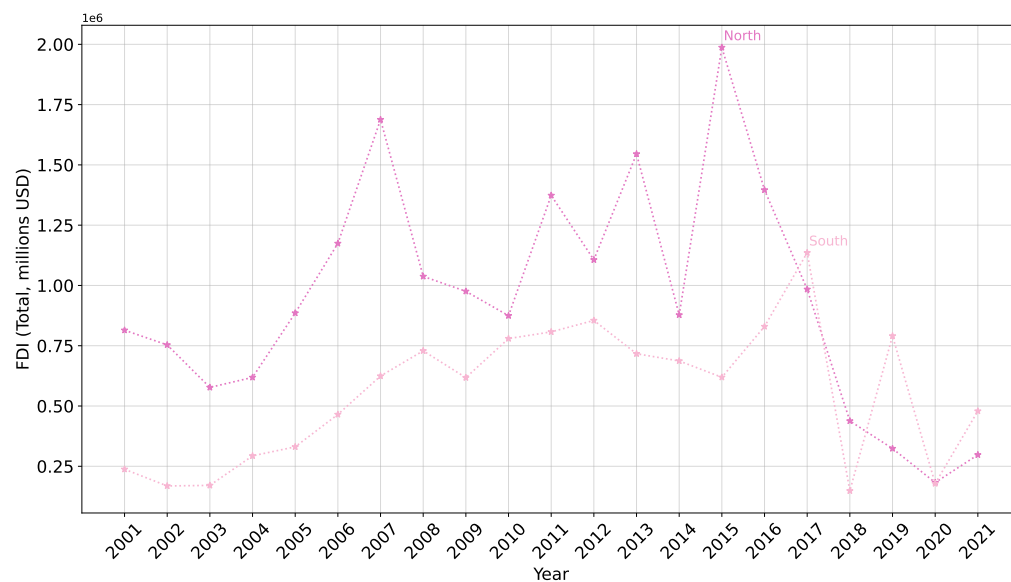


(a) FDI inflow

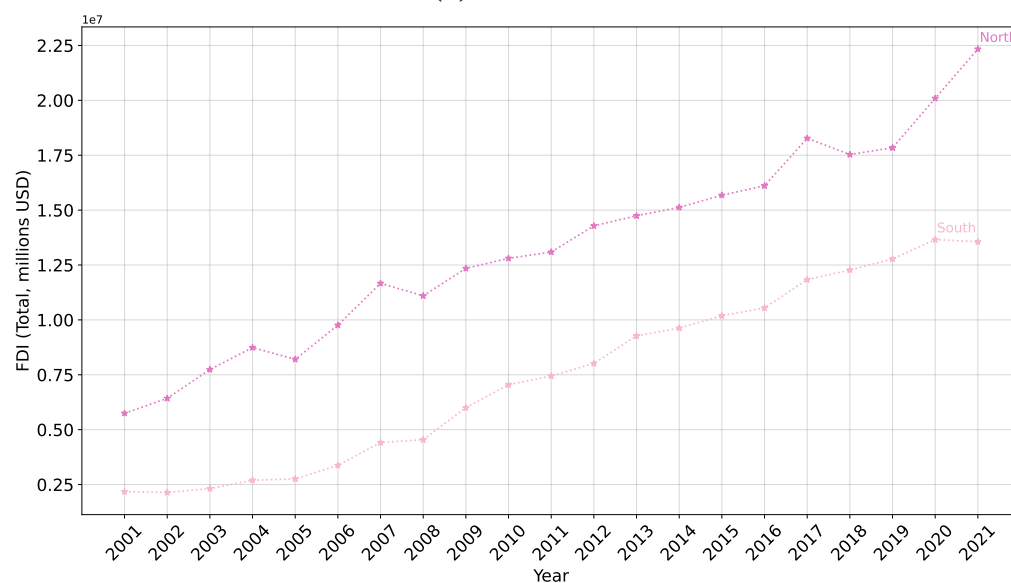


(b) FDI stock

Figure 5.B11: Total FDI Evolution by income group



(a) FDI inflow



(b) FDI stock

Figure 5.B12: Total FDI Evolution by geographic groups

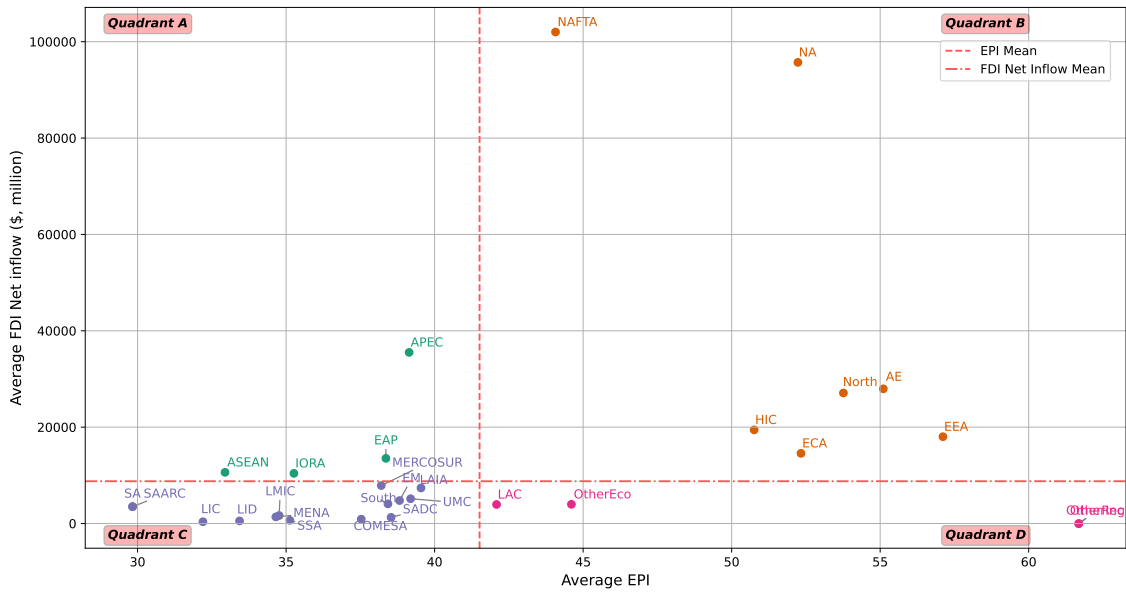


Figure 5.B13: Relationship between EPI and FDI inflow

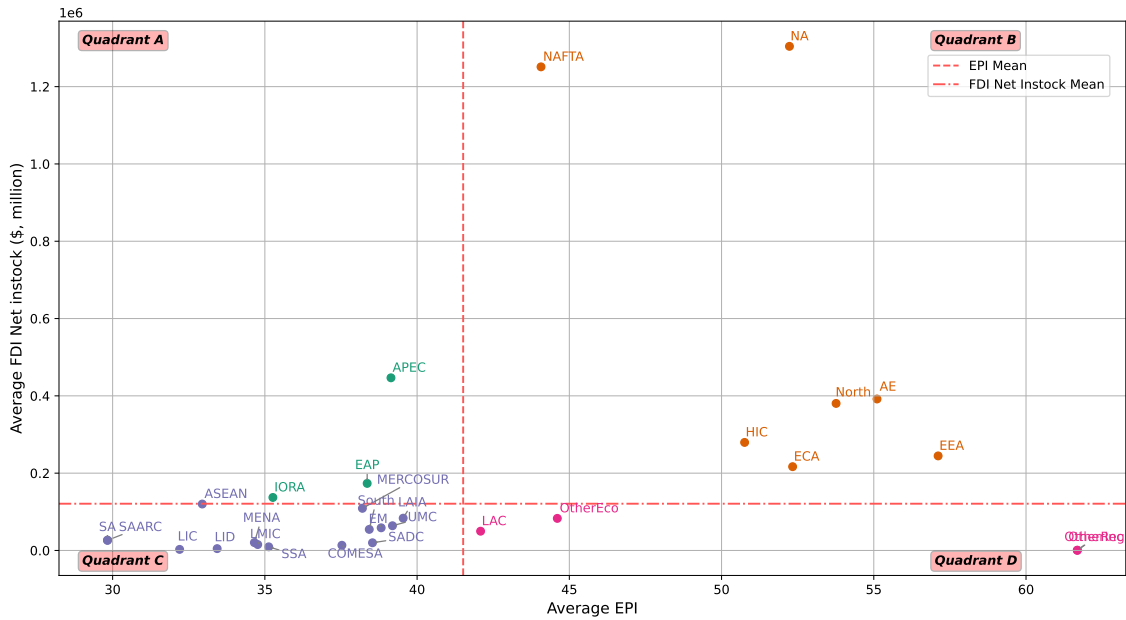


Figure 5.B14: Relationship between EPI and FDI stock

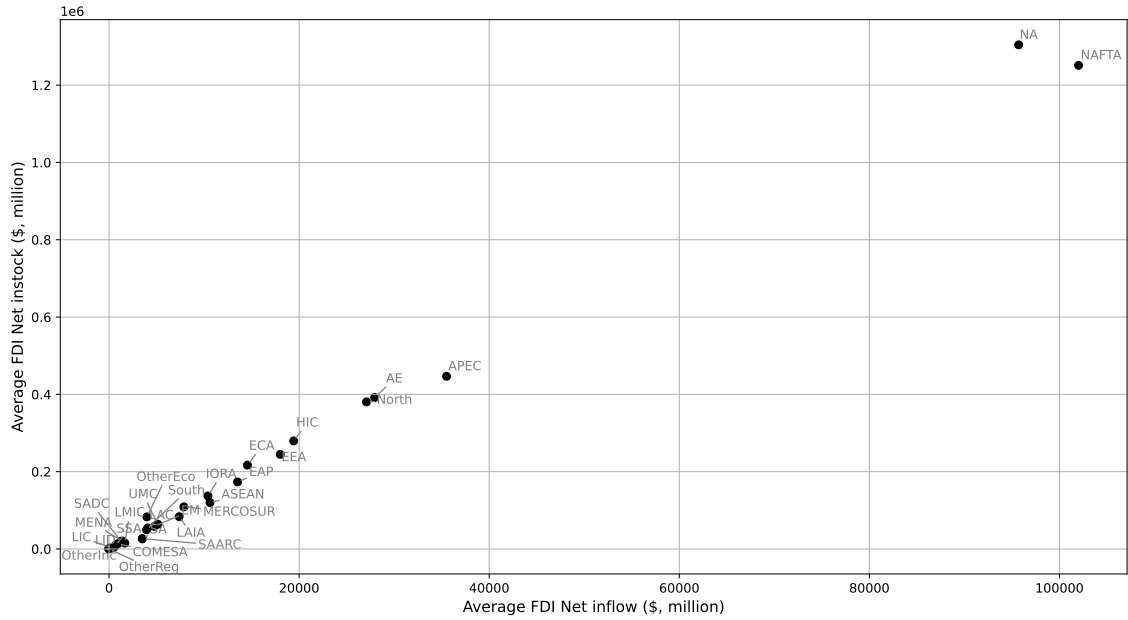


Figure 5.B15: Relationship between FDI inflow and stock

6

How bilateral FDI influences environmental convergence¹

Abstract: This paper analyzes environmental convergence and its determinants. We construct our analysis in a bilateral setting and hypothesize that, through foreign direct investment (FDI), one or more investor countries could impact the environmental performance of their hosts, leading thus to a possible environmental convergence between home and host economies. To do this, we construct an original database on bilateral FDI encompassing 128 countries for the period 2000-2012. Our results suggest that, in general, FDI does not directly impact environmental convergence, except for the case of FDI originating from major investor countries. Under specific conditions, FDI can be expected to influence environmental convergence along with other variables such as GDP per capita, industrial development, geographical proximity, or cultural and historical ties. Overall, these effects may vary depending on the type of partnership considered (North-North, North-South, South-North, and South-South).

Keywords: Environment, FDI, Convergence, Bilateral approach

JEL Codes: F21, F23, Q56

¹This chapter is co-written with Camelia TURCU (University of Orléans) and published in *The World Economy*. See Ahouangbe, V. L., Turcu, C. (2024). How bilateral foreign direct investment influences environmental convergence. *The World Economy*, 47(1), 37-95. URL: <https://doi.org/10.1111/twec.13532>

6.1 Introduction

Environment-related questions have been put at the forefront of the economic debate in the recent period, particularly concerning countries' pursuit of sustainable growth paths. Within this framework, environmental regulation has been considered crucial, capturing the environmental concerns and the corresponding government-level responses. Stricter environmental regulation can serve as a means to combat pollution and environmental degradation, making it instrumental in achieving improved environmental performance. At the same time, stringent environmental regulations can be perceived as a potential barrier to trade and foreign direct investment (FDI) which are key drivers of economic growth. Consequently, the interplay between economic development, the environment, and globalization (i.e., FDI) becomes complex and multifaceted. This becomes all the more important as in recent decades, foreign direct investment flows have witnessed a significant and noteworthy surge, not only in advanced economies but also in emerging and developing ones. Figure 6.B1, in the Appendix, illustrates the evolution of net FDI flows (inflows and outflows) over the period 1985 to 2012. We note that FDI flows have grown very rapidly during this period. Whereas in 1985, their value was \$44.23 million for net inflows, and \$51.78 million for net outflows, in 2007, before the Global Financial Crisis (GFC), it reached \$2235.19 million for net inflows, and \$2222.14 million for net outflows. The effects of these investments on economic activity and the environment could have been substantial.

The literature on the FDI - environment nexus² shows a two-way relationship. On the one hand, the environment exerts influence on FDI, particularly on the FDI location. On the other hand, FDI affects the environment. Our study aims to delve deeper into this latter relationship. When one country invests in another, it anticipates a conducive environment for its investments. Such investments generally facilitate the transfer of technology, practices, and systems, encompassing economic, financial, and cultural aspects (Javorcik and Spatareanu, 2011). These practices developed by companies can easily spread and influence the management habits of

²The link between FDI and the environment is often described by two key approaches widely discussed in the literature: the Pollution Haven Hypothesis (PHH) and the Pollution Halo Hypothesis (PHL). However, the existing literature offers mixed results for both of these hypotheses.

local companies or the entire entrepreneurial system in the host country ([Javorcik and Spatareanu, 2011](#); [Smarzynska Javorcik, 2004](#)). Thus, a convergence can arise in the economic, institutional, and financial systems and lead to similar environmental practices between partner countries. However, there are cases where differences in practices between the investor country (i.e., home country) and the FDI-receiving partner (i.e., host country) are present, possibly leading to environmental divergence.

Our study contributes to an expanding body of literature on environmental convergence. Environmental convergence can be assessed using various statistical methods and can encompass different facets of environmental regulation or outcomes. Typically, these aspects are explored mainly through convergence analysis within groups of countries. Several statistical approaches are used in this respect including conditional or unconditional/absolute beta-convergence, sigma convergence, or stochastic convergence.

Unlike these approaches that analyze how groups of countries converge together, our approach takes a different perspective. It analyzes whether and how one or more partner investor countries could impact the environmental policy of their host country of investment, and thus possibly generate an environmental convergence. To do this, we construct two types of environmental convergence: first, we compute the convergence at the bilateral level, where we assume that the home country could influence the environmental policy of the host economy; and second, we assess the convergence of the host country to the average environmental performance of the partner investor countries. In our analysis, we distinguish several forms of heterogeneity, depending on whether the home and host countries are Northern (OECD country) or Southern (non-OECD country) economies, or according to the direction of FDI flows (North-North, North-South, South-North, South-South).

Additionally, we compute the environmental convergence using different indicators, capturing alternatively either the environmental regulation dimension (e.g. Environmental Performance Index) or the environmental outcomes (e.g. CO₂ emissions). Typically, in the literature, it is common for studies to focus on only one of these two dimensions at a time³. However, in our paper, we consider these two

³See for example, [Herrerias \(2013\)](#) which analyzes environmental convergence in terms of CO₂ emissions or [Camarero et al. \(2013\)](#) who considers three types of pollutants and eco-efficiency indicators to compute the environmental convergence.

ways of assessing environmental convergence (e.g. in terms of environmental regulation and in terms of environmental outcome) to provide a more comprehensive view of the subject, to better understand how environmental convergence can be achieved, and to identify the factors that influence it. These insights may serve as key elements to be further explored at the policy level in order to understand the design of environmental agreements that are signed, ratified, and implemented across countries.

To the best of our knowledge, this is the first study to employ a bilateral approach between partners to analyze environmental convergence. To do this, we construct a bilateral database with 8140 partner country pairs, using data on 128 countries. The study covers the period from 2000 to 2012.⁴

In particular, our paper, aims to answer the following questions: (i) can an investor partner country (i.e. FDI home country) influence the environmental policies of the host countries receiving the FDI? (ii) is there an environmental convergence (in bilateral terms and to the average) between FDI home and host economies? (iii) what are the determinants of this convergence? (iv) would the economic power of the investing countries matter?

Our empirical results suggest that FDI does not directly impact environmental convergence, except in the case of the most important investor countries. Under certain conditions, FDI can be expected to affect environmental convergence. These conditions are more closely associated with the characteristics of the host country than those of the home country. The factors that directly influence environmental convergence are economic development, industrialization, and energy use, together with spatial, geographical, cultural, and historical ties. Threshold effects are identified concerning the level of economic development and industrialization. Environmental convergence whether bilateral or to the average is associated with high levels of economic development of the country pairs. The effects may vary depending on the type of FDI partnerships under consideration (South-South, North-South, South-North, North-North). Furthermore, the results also highlight that when home countries' investment represents a large share of the total FDI received by the host country, their FDI has a more pronounced impact on the environmental performance

⁴The timespan is limited by the data availability.

of their host economies.

The rest of the paper is organized as follows. Section 6.2 presents the literature review. Section 6.3 develops the methodology. Further, section 6.4 presents the variables and the data, and section 6.5 discusses the results. Finally, section 6.7 concludes.

6.2 Literature review

In this section, we begin by reviewing the existing research on the FDI-environment nexus.⁵ We further explore the literature on environmental convergence.

6.2.1 FDI and environment

The FDI-environment relationship operates in both directions.⁶ Foreign direct investment (FDI) can influence the levels of pollution or environmental regulations, while differences in environmental quality (pollution or regulation) between countries or geographical areas can, in turn, impact the FDI location. Consequently, we can differentiate between, on the one hand, the way the environment can affect FDI, and on the other hand, the impact of FDI on the environment.

Regarding *the impact of the environment on FDI*, a seminal theoretical paper is the one of Baumol and Oates (1988). Their model shows that a country with strict environmental regulation (e.g. a developed country) will face a comparative disadvantage in the production of dirty products, while the opposite holds for countries with lenient environmental regulations (e.g. developing countries). Several works, such as Markusen et al. (1995, 1993, 1992), Motta and Thisse (1994), Tang (2015), and Candau and Dienesch (2017), have contributed to this theory.

Empirically, the results related to the influence of the environment on FDI (or its locations) are nuanced, due to differences in methodologies, samples, periods under analysis, or variables used to measure the rigor of environmental policy. In addition, while the first studies focus on aggregated data at the country level with cross-sectional data, the most recent ones are more diverse (using different spatial

⁵For a detailed overview of the relationship between FDI and the environment, see Cole et al. (2017); Zhang (2013); Rezza (2015); OECD (1997). These studies provide a comprehensive analysis of the FDI-environment relationship.

⁶This bi-directional relationship highlights the endogeneity in the FDI-environment nexus, which requires careful consideration (e.g. Millimet and Roy (2016) and Fredriksson et al. (2003) treat the variable of environmental policy or regulation as endogenous, while Cole et al. (2006) treat FDI as endogenous).

units: countries, cities, regions) and employ more advanced econometric approaches (?).

This literature has mainly focussed on testing the validity of the Pollution Haven Hypothesis (PHH).⁷ A strand of this literature has confirmed the validation of PHH: [Cai et al. \(2016\)](#) or [Wang et al. \(2019\)](#) in the Chinese case, or [Sarkodie and Strezov \(2019\)](#) in the case of five major emitters of greenhouse gases, including China, India, Iran, Indonesia, and South Africa. Moreover, several other studies conducted in different regions have also provided a validation of the PHH.⁸

Oppositely, a second strand of the literature does not confirm the PHH and argues that stricter environmental standards can attract polluting companies. ? show that Japanese FDI in five polluting industries tends to be drawn to countries with a transparent and stable environmental regulatory framework. The results of [Tole and Koop \(2011\)](#) support these findings.

A third strand of the literature challenges the validation of the PHH by asserting that the environment does not significantly impact FDI. [Shao et al. \(2019\)](#) uses a panel vector error correction (VECM) model and co-integration techniques for two groups of countries - BRICS (Brazil, Russia, India, China, and South Africa) and MINT (Mexico, Indonesia, Nigeria, and Turkey) - over the period 1982-2014. They refute the PHH. Other studies that fall within this category include [Manderson and Kneller \(2012\)](#) analyzing outward FDI of British firms, [Raspiller and Riedinger \(2008\)](#) examining French firms, [Javorcik and Wei \(2003\)](#) studying 25 economies of Eastern Europe and the former Soviet Union or [Dean et al. \(2009\)](#) investigating the Chinese case. In sum, the empirical evidence on PHH validation is mixed.

Concerning *the impact of FDI on the environment*, the theoretical mechanisms by which the search for growth, through a change in trade and foreign investment policy ([Zhang, 2013](#)), can affect the level of pollution and depletion rate of scarce environmental resources has been analyzed by [Grossman and Krueger \(1991\)](#) and

⁷According to PHH, developed countries, facing strict environmental regulations at home, may transfer their environmentally hazardous industries to less developed countries with more relaxed environmental policies. It is thus possible that certain less advanced economies become pollution havens where other economies relocate their polluting industries.

⁸See, for example, [Shahbaz et al. \(2019\)](#) for countries in the Middle East and North Africa between 1990 and 2015, [Nasir et al. \(2019\)](#) for ASEAN emerging economies, [Chung \(2014\)](#) on Korean FDI, [Kheder and Zugravu \(2012\)](#) on French FDI, [Hanna \(2010\)](#) in the United States, or [Wagner and Timmins \(2009\)](#) in Germany

Grossman (1995). They distinguish three theoretical mechanisms: the scale effect, the composition effect, and the technical effect.⁹

While several studies have analyzed the impact of environmental regulations on firms' location (in search of PHH), there is a thin, but growing, empirical literature on the effects of FDI on the environment. Cole et al. (2017) suggests a classification of studies on the effects of FDI on the environment into three groups. The first group analyzes whether, in developing countries, foreign firms are cleaner than domestic ones. The second investigates whether there is evidence that the environmental performance of domestic companies is improving due to the presence of foreign companies. The third, in general, studies whether the presence of FDI leads to environmental improvements in the host country. Our research is in line with this specific approach.

Several key events have shaped the development of the literature on the environmental effects of FDI. On the one hand, the volume of FDI from developed countries to developing ones and between emerging economies is larger and has attracted much more attention. On the other hand, developed countries are supposed to have more stringent environmental policies than developing countries. Therefore their multinationals are likely to have "cleaner" technologies than the ones of emerging and developing countries. As a result, many studies focus on OECD countries (Cole et al., 2017; Zhang, 2013). These studies seek to confirm or refute the Pollution Halo hypothesis (PHL). PHL argues that developed countries are transferring technologically advanced and environmentally friendly FDI and better environmental standards to developing economies. Therefore, FDI from developed economies contributes to improving the environmental quality of host developing countries.

⁹The scale effect refers to the negative impact of economic production on the environment. The expansion of economic activity, induced by an increase in foreign investment, might generate, *ceteris paribus*, an increase in pollution as well as in the use of natural resources. The composition effect, on the other hand, highlights that FDI can impact pollution by modifying the industrial structure. It can promote the shift of production from a pollution-intensive sector to a low-pollution sector, or vice versa. The technical effect admits that the effect on the environment will depend more particularly on production techniques. On the one hand, foreign FDI can bring "cleaner" environmental technologies, and therefore less polluting and resource-intensive. On the other hand, multinationals can also increase residents' incomes (through job creation) - also called the income effect (Zarsky, 1999) - and lead to a greater demand in terms of environmental quality resulting in pressure on the government. However, this technical effect also suggests that more or less rigorous environmental management practices should also be taken into account (as foreign companies can bring "dirty" and more environmentally damaging technologies to countries or regions where environmental regulations are weak).

However, as the FDI flows originating from the South, particularly South-South flows (e.g. China to Africa), have increased, a growing number of studies have focused on emerging countries, particularly China ([Zhang, 2013](#)). These studies are conducted at an aggregate level (i.e., country or region), or at a micro level (i.e., firms) and do show mixed results.

Other strands of the literature consider that FDI has a positive impact on the environment. [Kirkulak et al. \(2011\)](#) examines FDI effects on air pollution in China, using 286 cities from 2001 to 2007. Using a cross-sectional data approach, time series, and panel data analyses, they show that the presence of FDI reduces air pollution. [Pazienza \(2019\)](#) investigates, using panel data techniques, the sign and magnitude of the impact that FDI inflows into the manufacturing sector in OECD countries has on the environment, and in particular on the amount of CO₂ from sectoral fuel combustion over the period 1989 to 2016. It highlights the impact of FDI on CO₂: as FDI increases, the development of the manufacturing sector grows, and CO₂ from fuel combustion decreases. This positive effect on the environment is explained by the fact that FDI is a driver of technological innovation and, therefore, a means of implementing greener and cleaner production methods. [Eskeland and Harrison \(2003\)](#) find that in developing countries foreign factories are significantly more energy efficient and use cleaner types of energy. [Cole et al. \(2008\)](#) find similar results in a study conducted on Ghana.

On the contrary, while some studies do not identify any impact of FDI on the environment, others do find negative effects. In the same vein as [Wang and Liu \(2019\)](#) who studies China, [Doytch and Uctum \(2016\)](#) show that FDI in developing countries has a detrimental effect on the environment. Further, [Lau et al. \(2014\)](#) find that FDI in Malaysia increases CO₂ emissions level.

The results of the literature on the effects of FDI on the environment, and the validation of PHL, are mixed. To understand why the results are so controversial, [Demena and Afesorgbor \(2020\)](#) conduct a meta-analysis of the effect of FDI on environmental emissions using 65 studies. They show that the underlying effect of FDI on environmental emissions is close to zero. But once the heterogeneity of the studies is taken into account, their results show that FDI significantly reduces environmental emissions. Their results remain robust after controlling for the presence

of disaggregated information (i.e. various levels of countries' development, different pollutants).

Overall, the outcomes of studies investigating the relationship between FDI and the environment have been highly diverse, as underlined by the meta-analysis conducted by [Demena and Afesorgbor \(2020\)](#) and [Rezza \(2015\)](#). However, a crucial insight derived from prior research is that the FDI's effects on the environment, and vice versa, can vary under distinct circumstances.

6.2.2 Environmental convergence

Several studies focus on conditional or unconditional/absolute beta-convergence of countries. In a beta-convergence perspective, all countries converge towards a steady state, and in this case, convergence is considered to be absolute. However, when certain characteristics can influence the long-run equilibrium, a conditional convergence is observed. Another form of convergence frequently explored is club convergence. Alternative methods of capturing convergence include employing stochastic terms and using a sigma-convergence process. The latter occurs when there is a decrease in disparities measured by any economic variable. In other words, the standard deviation or the coefficient of variation of the specific considered variable decreases over time. Stochastic convergence refers to the return to the deterministic mean/trend after a shock.¹⁰

For example, [Brännlund and Karimu \(2018\)](#) analyze the existence of a beta-convergence in terms of environmental and economic performances across 94 countries from 1971 to 2008. The results support the beta-convergence of environmental performance and a slower rate of convergence for high-income countries compared to low-income countries. [Brännlund et al. \(2015\)](#) use a dataset of the Swedish manufacturing sector covering 14 industrial sectors over the period 1990-2008. The results show the presence of conditional beta-convergence in CO₂ performance among industrial sectors in Sweden. The higher the capital intensity, the lower the rate of convergence towards the different stationary states. [Yu et al. \(2018\)](#) focus on the period 1995-2015 and includes a larger number of industrial sectors, totaling 24. They find the presence of a beta-convergence, and robust club convergence for 20 sectors, and show that capital intensity and the added value of sectors per capita

¹⁰For a comprehensive literature on environmental convergence, see [Yu et al. \(2018\)](#).

are factors that can influence the convergence process. [Apergis and Payne \(2017\)](#) study 50 US states over the period from 1980 to 2013. They find evidence of a club convergence: several clubs are identified based on sector and fossil fuel sources.

[Fallahi and Voia \(2015\)](#) study the stochastic convergence of per capita energy consumption in a group of 25 OECD countries over the period 1960-2012. They find that countries like Australia, Austria, Belgium, Denmark, Finland, Greece, Italy, Japan, Luxembourg, the Netherlands, Norway, Spain, and Switzerland converge. [Camarero et al. \(2008\)](#) develops a *SURE* approach, using CO2 emission and GDP to generate Environmental Performance Indicators. They further test the convergence of environmental performance and show that OECD countries are catching up with Switzerland. [Camarero et al. \(2013\)](#) show the existence of a club convergence for OECD countries in terms of CO2 emissions, in line with [Ulucak and Apergis \(2018\)](#).

A key takeaway of the literature is that, in testing the convergence, whatever form it has, it is crucial to take into account the countries' characteristics. Hence, in the next section, we investigate whether environmental convergence among FDI partners - whether bilateral or to the average - is affected by bilateral FDI and other specific country characteristics, and identify how countries' dominance in FDI flows can explain the environment-FDI nexus.

6.3 Methodology

As previously mentioned, our objective is to analyze environmental convergence between FDI partner countries while emphasizing the effects of FDI flows on this convergence. To do this, we construct an original bilateral approach. In addition, we aim at analyzing the heterogeneity of the effects according to the FDI home and host country (North or South economy). This supposes taking into account the type of FDI flows: North-North, North-South, South-North, and, South-South.

6.3.1 Baseline model

To investigate the bilateral environmental convergence across FDI partner countries, we construct our baseline empirical specification as follows:

$$EnvGAP_{ijt} = \beta_0 + \beta_1 FDI_{ijt-1} + \beta_2^k X_{it-1}^k + \beta_3^k X_{jt-1}^k + \{\beta_4^m Z_{ij}^m\} + \mu_{ijt} \quad (6.1)$$

The index i translates the FDI host country; j , the FDI origin or home country; and t , the year. The dependent variable $EnvGAP_{ijt}$ captures the level of environmental convergence. It is measured by the absolute value of the difference between the environmental performance of FDI host country i and home country j at time t , $EnvGAP_{ijt} = |Env_{it} - Env_{jt}|$. Env is an indicator of environmental quality. It is constructed using indexes of environmental performance (i.e., the efforts and rigor of environmental policy in a given country). In the baseline model presented in the Results section, Env corresponds to the Environmental Performance Index (EPI). In the Robustness section, Env is captured by variables translating the environmental outcomes (i.e., CO2 emissions).

FDI_{ijt-1} is the FDI in the host country i coming from home country j at time $t - 1$. Throughout our analysis, we use lagged variables of FDI flows to circumvent endogeneity problems (Cole et al., 2006). β_1 is a key parameter for our analysis. It determines whether FDI flows have an effect on the environmental gap between two partner countries. If this parameter is significant, then FDI flows¹¹ tend to affect the environmental gap between two partner countries. If this parameter is statistically significant and negative, it indicates that FDI fosters a reduction of the environmental gap between the two partner countries, promoting a greater environmental convergence between them. The reverse applies when β_1 is significant and positive. When β_1 is not statistically significant, FDI is not considered a determinant of the environmental gap between country pairs.

The vectors X_i and X_j represent the control variables of host i and home country j respectively. Indeed, X is a vector of k control variables, including the *development level*, that captures a wealth effect (e.g. it is assumed that a more economically developed country will demand a “cleaner” environment by putting pressure on the government); the *urbanization rate* allowing to control for the increased exposure to industrial pollution suffered by citizens of more urbanized countries; the *manu-*

¹¹As the analysis is constructed into a bilateral framework, FDI being the flow between countries i and j , we keep this variable expressed in terms of flows in line with the literature, see Demir (2016); Demir and Duan (2018).

facturing sector allowing to control for the size of the manufacturing sector within an economy, considering, in line with the literature, that this sector is more capital intensive and hence generates more pollution compared to other sectors (i.e. services, agriculture); and finally, *energy use* to capture how a country takes into account the environmental challenge through the consumption of (renewable, often less polluting) energy. In addition to these variables, we also integrate in X the square of the control variables except for energy use¹². This allows us to account for the existence of threshold effects. The square of the *development level* evokes the environmental Kuznets curve, while the square of the urbanization rate or of the share of manufacturing added value in GDP allows us to take into account threshold effects (Potters and Sloof, 1996).

Since our specification (Equation (6.1)) is constructed in a bilateral approach, we add a vector Z composed of m additional control variables. This vector includes information on the distance between countries i and j , shared language and border, and colonial and cultural background. This information is time-invariant between the two partner countries i and j over the analyzed period. As a result, the information contained in $\{Z_{ij}^m\}$ is also used in $\{\omega_{ij}\}$. The introduction of $\{\omega_{ij}\}$, which encompasses all time-invariant information between i and j , would systematically lead to the exclusion of $\{Z_{ij}^m\}$. In the first step of the convergence analysis, we will not introduce the term $\{\omega_{ij}\}$ so that we can capture the information contained in $\{Z_{ij}^m\}$. It is interesting to check how certain forms of geographical proximity (distance, landlocked country or not), spatial proximity (common border), cultural proximity (common language), and historical proximity (colonization, same country, but currently dislocated) can impact the environmental gap (and lead to convergence).

The term μ_{ijt} can be written as follows: $\mu_{ijt} = \eta_i + \tau_j + \nu_t + \{\omega_{ij}\} + \epsilon_{ijt}$. η_i translates the host-country-specific fixed effect i , capturing the time-invariant constant term, which varies only across host countries. τ_j represents the home-country-specific fixed effect j , capturing the time-invariant constant term, which varies only across home countries. ν_t represents the time-specific effect, capturing the constant term invariant for all (partner) countries, which varies only over time. ω_{ij} represents the partner country pair-specific effects, capturing everything that is not

¹²We also run regressions with the square of the energy use. Nevertheless, the effects of this squared indicator are not robust over the estimations. These results are available upon request.

varying over time for two partner countries i and j . ϵ_{ijt} represents the assumed independent and identically distributed idiosyncratic error.

6.3.2 Further specifications

In the following, we address the **heterogeneity** of the FDI host and home countries (i.e. North or South economies) and search to identify the **conditions** that can enhance the environmental convergence across countries in the presence of FDI.

To take account of the heterogeneity of the host economy, we expand our baseline model (6.1) to introduce a binary variable N_i which becomes equal to 1 when the host country is a Northern country and 0 otherwise. Hence, the equation becomes:

$$\begin{aligned} EnvGAP_{ijt} = & \beta_0 + \beta_1^1 FDI_{ijt-1} + \beta_1^2 N_i \times FDI_{ijt-1} + \beta_2^k X_{it-1}^k + \beta_3^k X_{jt-1}^k \\ & + \{\beta_4^m Z_{ij}^m\} + \mu_{ijt} \end{aligned} \quad (6.2)$$

According to this equation, β_1^1 represents the effect of FDI flows on the bilateral convergence of Southern countries with their FDI partner (North or South), and $\beta_1^1 + \beta_1^2$ the effect of FDI flows on the bilateral convergence of Northern countries with their partner (North or South).

We also consider the heterogeneity of the FDI home country: thus, we introduce a binary variable N_j that is equal to 1 when the FDI home country is a Northern country and 0 otherwise. The equation that will be tested is the following:

$$\begin{aligned} EnvGAP_{ijt} = & \beta_0 + \beta_1^1 FDI_{ijt-1} + \beta_1^2 N_j \times FDI_{ijt-1} + \beta_2^k X_{it-1}^k + \beta_3^k X_{jt-1}^k \\ & + \{\beta_4^m Z_{ij}^m\} + \mu_{ijt} \end{aligned} \quad (6.3)$$

In this case, β_1^1 translates the effect of FDI on bilateral convergence between their Southern home country and their host economies (North or South), and $\beta_1^1 + \beta_1^2$ the effect of Northern FDI on bilateral convergence between their home countries and their host economies (North or South).

Taking account of the heterogeneity of host countries (Equation (6.2)) and of the home countries (Equation (6.3)), i.e. according to the type of flow (North-North, North-South, South-North and, South-South), we can re-write Equation

(6.1). Hence, the new model to be tested is the following:

$$\begin{aligned} EnvGAP_{ijt} = & \beta_0 + \beta_1^1 FDI_{ijt-1} + \beta_1^2 N_i \times FDI_{ijt-1} + \beta_1^3 N_j \times FDI_{ijt-1} \\ & + \beta_1^4 N_i \times N_j \times FDI_{ijt-1} + \beta_2^k X_{it-1}^k + \beta_3^k X_{jt-1}^k \\ & + \{\beta_4^m Z_{ij}^m\} + \mu_{ijt} \end{aligned} \quad (6.4)$$

According to this specification, the effect of North-North FDI can be calculated as $\beta_1^{NN} = \beta_1^1 + \beta_1^2 + \beta_1^3 + \beta_1^4$, that of North-South FDI is $\beta_1^{NS} = \beta_1^1 + \beta_1^3$, that of South-North FDI is $\beta_1^{SN} = \beta_1^1 + \beta_1^2$, that of South-South FDI is $\beta_1^{SS} = \beta_1^1$. The interpretation of the β_1 parameter in the initial equation is also valid for β_1^{NN} , β_1^{NS} , β_1^{SN} , and β_1^{SS} .

6.4 Variables and data

Unlike most studies in the literature, that use a single indicator to measure environmental performance or quality, such as CO₂, SO₂, NO_x, etc., in our analysis we employ a more comprehensive approach to measure environmental performance. Hence, we use the EPI (Environmental Performance Index). This version of EPI is constructed from two major weighted indices, including environmental health and ecosystem vitality, generated from 22 indicators.¹³ The environmental policy data is taken from SEDAC (Socioeconomic Data and Applications Center) and Yale Center for Environmental Law and Policy.¹⁴ EPI ranges from 0 (poor environmental quality) to 100 (good environmental quality). The data is available only for the period 2000 to 2010.

FDI is measured by net inflows and expressed in millions of USD. The data on bilateral FDI comes from OECD (Organization for Economic Co-operation and Development), UNCTAD (United Nations Conference on Trade and Development) databases, statistical offices, also from author sources (Demir, 2016; Demir and Duan, 2018), and initially covered the period 1990-2012. We supplement the data

¹³The indicators are: infant mortality, indoor air pollution, particulate matter, access to clean water, access to sanitation, SO₂ emissions per capita, SO₂ emissions per GDP, change in water quantity, biodiversity protection, marine environmental protection, critical habitat protection, agricultural subsidies, pesticide regulation, plant material change, forest loss, forest cover change, overexploited fish stocks, fishing pressure on the coastal shelf, CO₂ per capita, CO₂ per GDP, CO₂ emissions per electricity generation, and renewable electricity.

¹⁴See Yale Center for Environmental Law and Policy - YCELP - Yale University, Center for International Earth Science Information Network - CIESIN - Columbia University, World Economic Forum - WEF, and Joint Research Centre - JRC - European Commission (2012)

with ITC's Investment Map to increase the size of the sample.¹⁵ Since the FDI data are expressed in current U.S. dollars, we deflate them by the U.S. GDP deflator (with a base year of 2012) from the IMF's World Economic Outlook (WEO). We also use aggregate net FDI flow data from the World Bank's WDI (World Development Indicator) and the OECD. These data have also been deflated in the same way.

In line with the literature, we use the following control variables: the development level, measured by GDP per capita (constant 2010 US\$); urbanization rate computed as the percentage of the total population living in urban areas; manufacturing which represents the share of added value in the manufacturing sector over GDP; energy use refers to the consumption of primary energy before transformation into other end-use fuels, it is expressed in kg of oil equivalent per capita. These data are from the World Bank's WDI data.

Several bilateral variables are employed. The (log) distance (km) between two countries i and j is used: it captures the diffusion costs of environmental rules or practices between countries. We hypothesize that a higher physical distance between two partner countries can reflect higher differences in environmental regulations or practices. It is generally accepted that as distance increases, countries will have less economic and cultural exchange, thus minimizing regulatory harmonization. On the contrary, sharing a common language and border facilitates the convergence of environmental policy by promoting the sharing of common environmental measures and facilitating thus the mutual understanding of the implemented regulations. Hence, we include two binary dummy variables, equal to 1 if i and j share a common language and a common border, respectively, and 0 otherwise. In addition, we include a landlockedness variable, which represents the number of landlocked countries in the country pairs (0 if neither partner is landlocked, 1 if one partner is landlocked, and 2 if both partners are landlocked). Three other binary variables will capture the effect of colonial ties. In line with the literature, we assume that the persistence of a common cultural heritage tends to increase similarities between countries. This effect will be captured by a binary variable equal to 1 if i and j (1) have had a common colonizer after 1945; (2) are in a current colonial relationship; (3) have had

¹⁵The ITC (International Trade Center) Investment Map data provide only inward FDI data and not the net value of inward flows. As a result, this data source is used as a last resort to fill in missing data and accounts for only 12 percent of the total information used.

a previous colonial link. Finally, we also include a dummy equal to 1 if i and j were part of the same country in the past, capturing possible similarity and dependence effects when it comes to regulation in the two countries (and thus, possibly, environmental regulations).

In terms of data processing, the bilateral FDI data suffer from missing values. In the aggregate analysis, we keep only those partner country pairs for which there is enough information over the analyzed period (i.e., for at least 6 out of the 13 periods)¹⁶. This allows us to compare the results of an aggregate analysis with those obtained in a bilateral analysis. The EPI data behind the *Env* variable in the baseline scenario also contains missing data. To tackle this, we inspect the index and the two main dimensions that generate it. We keep only those countries for which we have enough information over the study period (i.e., for at least 7 out of the 13 analyzed periods). Since historical data on the environment is only available for the period 2000 to 2010, and FDI data stops in 2012, we limit our analysis to the period 2000 to 2012 (13 periods).¹⁷

The introduction of explanatory variables that are lagged by one period results in the loss of one year and a reduction in the sample size. To circumvent this, for our explanatory variables considered in $t - 1$, the analyzed period is 1999-2012. Hence, we add the data for the explanatory variables for the year 1999. To mitigate the effect of outliers, the variables capturing the manufacturing and energy use are winsorized at the 1st and 99th percentiles of their empirical distribution.

We end up with 128 countries in the aggregate database, and 8140 country pairs in the bilateral database. The study covers the period from 2000 to 2012. In the remainder of our work, we consider Northern countries as OECD countries and Southern countries as non-OECD countries (Demir, 2016). The list of countries is

¹⁶We also run regressions with data on bilateral FDI, our key explanatory variable, for which there is information for at least 7 out of the 13 periods. The results do not change.

¹⁷Due to the lack of reliable data for 2012, and the non-existence of sufficient data for 2011, we have generated environmental protection indexes for these two years. For each year, we use the average annual growth rate of the last three years of EPI to generate its missing values. We do this for two reasons. First, we focus on the last 3 years, especially after 2008, instead of considering the whole period, as we observed a shift in the dynamics of environmental efforts following the Global Financial Crisis (see Figure 6.B2). In fact, in the immediate period after 2008, economic recovery might have been more in the spotlight compared to environmental policy issues (Tienhaara, 2010). Second, EPI is an index that is not highly volatile. Its slope is relatively constant over time: hence, using the average annual growth rate to generate the data can be considered as a suitable approach.

provided in Appendix A. For the sake of consistency, we maintain the groups of countries constant over time and do not permit any country switching.

6.5 Results and discussion

6.5.1 Descriptive analysis

Table 6.C1 presents the descriptive statistics of our variables. We insist on two variables namely the environmental gap and the FDI, which are central to our analysis. The average environmental gaps between North-North partners (7.413) and South-South ones (8.999), respectively, are lower than those characterizing North-South partners (13.4), and South-North ones (13.21). In addition, the standard deviation of the EnvGap variable (computed based on EPI) is smaller between Northern countries (5.819), and Southern ones (6.673) respectively than between North-South partners (8.76), and South-North ones (8.69). This suggests a homogeneity of intra-group environmental performance within the Northern country group or the Southern country group, respectively, but a significant gap in environmental performance between the North and South (North-South, South-North). This is supported by Figures 6.B4 and 6.B3.

In Figure 6.B3¹⁸, the curves representing the average gap of North-South and South-North environmental performance is higher than that of North-North and South-South countries over the entire period. In addition, Figure 6.B3 shows the evolution of the average environmental gap over time. It underlines that the average gap line in environmental performance between any two partner countries (World line) exhibits a slightly positive slope until 2008. However, the slope becomes relatively flat afterward. This suggests that prior to 2008, country pairs tended to gradually diverge in terms of environmental performance. However, after 2008, they seem to have generally maintained their gaps in environmental performance. The same is observed when analyzing the environmental gaps between country pairs belonging to North-South or South-North groups, respectively. The positive slope of the curves (North-South and South-North lines) before 2008 suggests that the environmental gap between the countries of the North and the ones of the South

¹⁸This figure also allows us to investigate whether, on average, over time and from an environmental point of view, two partner countries are moving apart (experiencing a bilateral environmental divergence) or getting closer (signaling a possible bilateral environmental convergence).

widened, giving rise to a possible bilateral environmental divergence; after 2008, the gap narrows, suggesting a certain bilateral environmental convergence. However, the trend is not the same inside the Northern countries group or the Southern countries one: the South-South line has a positive slope, suggesting a possible bilateral environmental divergence between the country pairs of the South; we observe the opposite for the country pairs of the North (the North-North line has a negative slope). In other words, while country pairs in the North seem to be converging in terms of environmental performance, the ones in the South seem to be moving further apart. Moreover, country pairs composed of a Northern and a Southern partner seem to be characterized by increasing environmental gaps till 2008 and slightly decreasing afterward.

Similar results can be found in Figure 6.B4 which shows the Kernel density of the environmental gap. It underlines also a higher similarity of environmental policies between partners within the Northern group or Southern group respectively, and a divergence between country pairs of North-South, or South-North groups.

The statistics on net FDI flows are presented in Table 6.C1. We note that the partners with the largest bilateral FDI flows are the North-North ones. Their average flow (\$712.7 million) is the highest, followed by global flows (\$163.9 million) in general, North-South (\$83.76 million), South-North (\$22.37 million), and South-South (\$77.97 million) ones. Moreover, the Northern countries allocate the majority of their FDI flows to other Northern partners rather than to Southern economies. Conversely, the Southern countries tend to invest on average more in their fellow Southern partners than in their Northern counterparts. This analysis highlights the idea of club investments over the period from 2000 to 2012, i.e. in 2012, countries invest more in similar partners belonging to the same group (North-North, South-South) than in more different partners belonging to more heterogeneous groups (North-South, South-North). The lowest flows are registered from the countries of the South to the countries of the North.

6.5.2 Baseline results

To properly specify our bilateral model, we use five different forms of regression presented in Table 6.C2. Column (1) presents the results of estimations with Ordinary Least Squares (OLS); column (2), OLS with time fixed effects (FE); column

(3), OLS including time and host country fixed effects; column (4) OLS including time, host country, and home country fixed effects; and finally, column (5) OLS with country pairs (host and home) fixed effects and time fixed effects. All results¹⁹ are presented with robust standard deviations (grouped into pairs of partner countries).

A criterion to choose the optimal specification for our analysis is the Root Mean Square Error (RMSE). The best model will indicate the lowest RMSE values. According to this criterion, the specification with fixed effects by pairs of partner countries and time fixed effects (column 5) emerges as the most suitable choice. However, it is important to note that the literature on environmental convergence emphasizes the role of spatial effects which need to be considered in some manner during the analysis. Unfortunately, the estimation with fixed effects by country pairs and with time-fixed effects (column 5) eliminates all the bilateral and spatial perspectives. To address this, we will instead use the estimate with OLS including time, host country, and home country fixed effects (column 4) to interpret our results. This estimate minimizes the RMSE values compared to columns 1 to 3 (if we exclude column 5) and allows us to keep the country pair-specific information. Since both estimates provide coefficients of the same signs and relatively of the same magnitude (with the exception of coefficients of FDI and home country GDP per capita), we will focus on the interpretation of the coefficients of column (4). This offers the advantage of analyzing the effects of spatial and geographical proximity, historical or cultural ties on bilateral environmental convergence, offering valuable insights for our analysis.²⁰ For the sake of robustness, in the next steps, we present where possible, the results for both OLS with the home country, host country, and time-fixed effects (as in column 4) and OLS with country-pair and time-fixed effects (as in column 5).

Based on the results of column (4), we note that FDI flows have a negative and significant effect on the environmental gap between partner countries at the 5%

¹⁹To avoid presenting the results with numerous decimals, we multiply our index of environmental quality, *EnvGap* by 100. Consequently, before interpreting the coefficients, we perform adjustments by dividing them by 100.

²⁰Based on the results of column (4), we note that some factors can encourage bilateral environmental convergence (having statistically significant and negative coefficients), while other factors (statistically significant and with positive coefficients) lead to bilateral environmental divergence (statistically significant and positive coefficients), and some have no effect (non-statistically significant coefficients).

threshold. On average, an increase in FDI flows of \$1 million appears to narrow the environmental gap between two partner countries by 0.000046 (0.0046/100), all other things being equal. Over the period from 2000 to 2012, on average, FDI led to a decrease of 0.0075²¹ in the absolute value of the spread in EPI indices (which captures the environmental gap) between two partner countries. While the effects seem small, they still carry a key signal: a bilateral environmental convergence might be at work. Nevertheless, it is worth acknowledging that the latter is a process that might require a considerable amount of time to fully materialize. In column (5), although the FDI coefficient remains negative, it is no longer statistically significant. This suggests that further robustness checks need to be conducted to confirm the effect of FDI on the bilateral environmental gap.

The GDP per capita of the host and home countries increase their bilateral environmental gap but up to a certain threshold.²² This effect seems non-linear. Particularly for host countries, there is a threshold effect, with the turn-around points between \$39689 (column 4) and \$62921 (column 5). This suggests that host countries (in particular low- and middle-income countries) tend to move away from the environmental performance of their investing partners. Nevertheless, beyond the GDP per head thresholds previously mentioned, countries tend to move closer to the environmental performance of their investing partners. Moreover, the investor countries (home countries) with a high level of GDP per head seem to converge with their partners which is not necessarily the case for investor economies with lower levels of economic development. Hence, overall, the link between the level of economic development (GDP per head) and the environmental gap follows an inverted U-shaped relationship. A bilateral environmental divergence between two partners might be associated with low levels of economic development of both partners, while a bilateral environmental convergence between partners is observed when they are highly advanced economies.

Non-linear effects are also observed when investigating the impact of the manufacturing sector on the environmental gap. At low levels of manufacturing in both investor (home) and host countries, a certain reduction of the environmental gap

²¹This is computed as follows: 0.000046×163.9 , where 163.9 is the mean of FDI flows.

²²We compute the threshold effect as follows: $\frac{-\beta_3^{GDP} \times 100}{2 \times (\beta_3^{GDP^2} / 100)}$.

between them can be observed. Nevertheless, beyond a certain threshold of manufacturing as a share of GDP, a certain increase in the environmental gap between host and home economies can be observed. The turnaround point for manufacturing value added as a share of GDP is between 70.37 (column 4) and 127.21 (column 5) for host countries, and from 100.53 (column 4) to 140.88 (column 5) for home countries. The relationship between manufacturing development and the environmental gap can take thus a U-shaped form. In other words, a bilateral environmental convergence can occur if the two partners have low levels of manufacturing development. Conversely, a bilateral environmental divergence between partners is observed when they both strongly rely on their manufacturing sectors.

Urbanization does not appear to be a significant explanatory determinant of environmental gaps between partners. However, the use of energy is a key factor impacting the bilateral environmental gap between partners. On average, all other things being equal, the higher the energy use in both host and home countries, the larger the environmental gap between them.

Spatial and geographical proximity also appears to be an important determinant of bilateral environmental convergence. Indeed, while sharing a common border between two partners significantly reduces the environmental gap between two partners by 3.27 (-327/100) units, higher distances between two partners can increase divergence in terms of environmental performance. A 1% increase in the distance between two partners leads to a corresponding 1.57-unit increase in the environmental gap. Nevertheless, there is no statistically significant effect of being two landlocked partners on the environmental gap.

Cultural or historical ties seem to have ambiguous effects on bilateral environmental convergence. On the one hand, sharing a common language or having had a colonial bond does not necessarily seem to support environmental convergence. Only the fact of having had a common colonizer after 1945 leads to a significant reduction of about 2.23 in the environmental gap between partner countries. On the other hand, the fact that two countries were part of the same country enhances the environmental divergence, through an increase in the environmental gap of 2.3 units. Being in a colonial relationship during the investigated time span does not significantly increase the environmental gap. In the next sub-sections, we will conduct a

more comprehensive analysis of the heterogeneities across countries.

6.5.3 Heterogeneity analysis

In this subsection, our analysis focuses on exploring heterogeneity based on the type of investing country (home country) - whether Northern or Southern -, the type of FDI receiving country (host country) - whether Northern or Southern -, and lastly, the type of FDI flows (South-South, North-North, South-North, North-South). Table 6.C3 presents the results obtained while considering the heterogeneities by type of FDI flow. In Table 6.C4 the results take account of the heterogeneity by home, or by host country, respectively.

As in the subsection above, we analyze in particular the results of the OLS estimate with time, host country, and home country fixed effects. They are displayed in columns (1) to (5) of Table 6.C3 and in columns (1) to (4) of Table 6.C4. As previously, we also present as robustness the estimates with time-fixed effects and country-pair fixed effects in columns (6) to (10) of Table 6.C3 and in columns (5) to (8) of Table 6.C4.

In Table 6.C3, columns (1) and (6), respectively, show the effects of the types of FDI flows on the environmental gap, in line with Equation (4).²³ In the remaining columns (2-5 and 7-10), we conduct a robustness analysis splitting our total sample into subsamples by each possible partnership or flow type. The results lead to the same conclusions as those displayed in columns (1) and (6). We do not notice a significant and robust effect of FDI flows on the environmental gap, whatever the type of flow or partnership being considered.

With regard to the other control and proximity variables, we find the same results as before (Table 6.C2) with some exceptions. Regarding environmental convergence between South-South partners, while the different control variables do not seem to have robust effects, the geographical and spatial proximity variables do. In addition, for OECD (North-North) partners, new elements are emerging. Note

²³North-North FDI flows' impact ($\beta_1^{NN} = \beta_1^1 + \beta_1^2 + \beta_1^3 + \beta_1^4$) is 0.00025 (p-value = 0.469) in column (1) and -0.0000069 (p-value = 0.8895) in column (6); North-South FDI flows' effects ($\beta_1^{NS} = \beta_1^1 + \beta_1^3$) are -0.00011 (p-value = 0.73) in column (1) and -0.000016 (p-value = 0.747) in column (6); South-North FDI flows' effects ($\beta_1^{SN} = \beta_1^1 + \beta_1^2$) are -0.000119 (p-value = 0.703) in column (1) and -0.000015 (p-value = 0.737) in column (6); and, South-South FDI flows' impact ($\beta_1^{SS} = \beta_1^1$) is -0.00032 (p-value = 0.292) in column (1) and -0.000026 (p-value = 0.563) in column (6). These effects are nevertheless not statistically significant.

the U-shaped relationship of the effects of urbanization and industrial development on environmental gaps between partners, and the inverted U-shaped relationship of the effect of economic development. Cultural (language, same country), geographical and spatial (distance, landlockedness, contiguity), or historical (colonial ties) proximity strongly impacts environmental differences. The factors that encourage bilateral convergence between Northern countries are contiguity, the same language, post-1945, and current colonial ties. For these same countries, two factors that lead to bilateral divergence are distance and isolation. For other forms of partnerships (North-South and South-North), the results (columns 8-9) are similar to those found for Northern partners for most of the control variables, with the exception of manufacturing development where the relationships are reversed for the host country (inverted U-shaped relationship, column 7) and the host countries (inverted U-shaped relationship, column 8). In addition, in this case, proximity variables do not impact the environmental gap between partners.

Table 6.C4 presents the findings on bilateral environmental convergence from a different perspective, by host or by home country, respectively. The objective is to assess whether: (i) a Southern host country - columns 1 and 5, respectively (or a Northern economy - columns 2 and 6, respectively) is subject to bilateral environmental convergence regardless of its partner; (ii) a host country narrows its bilateral environmental gap with investor partners which are from the North (columns 3 and 7, respectively) or from the South (columns 4 and 8, respectively). It should be noted that, whatever the situation that is considered, FDI flows do not affect the bilateral environmental gap between partners. The other determinants of environmental convergence are relatively the same as those underlined by our previous results.

6.5.4 Convergence to the average environmental performance of investor partners

Our approach might give rise to a valid criticism that deserves consideration. A country often deals with multiple investor partners that can influence its environmental policy, and vice versa. When several partners begin to exert their influence on a single country, the latter may consider implementing policies in order to maintain positive relationships with all partners. Consequently, the country will not

follow a bilateral environmental convergence path but rather move towards reaching a convergence with several partners. To test this hypothesis, we examine the environmental convergence to the average of the investor partners. Thus, our dependent variable is adjusted as follows: $\overline{EnvGAP}_{ijt} = |Env_{it} - Env_{jt}|$ where, for a given country i , Env_{jt} represents the average of the environmental performance of the n partners at time t and is calculated as follows: $Env_{jt} = \frac{1}{n} \sum_{j=1}^{j=n} Env_{jt}$.

Table 6.C5 presents the results of regressions run with time-, host-, and home-fixed effects.²⁴ We consider the heterogeneity according to the type of host country (Northern country in column 2, or Southern country in column 3) that converges to the average of its partners, or according to the type of partners (Northern in column 4, or Southern in column 5) towards whose environmental performance average the host country might converge. In addition, we also investigate whether a country converges on average to partner countries in the same group as itself. The results are shown in column (6) for the club of Northern countries and in column (7) for the group of Southern countries. Moreover, we also test the average convergence across clubs. In other words, we aim to assess if the groups of investor countries (belonging to the North in column 8, and to the South in column 9) influence the environmental policy of the host economies. For instance, we explore potential environmental convergence between a Northern (Southern, respectively) host country to the average of its Southern (Northern, respectively) partners. Whatever the type of convergence under consideration, FDI flows do not show a statistically significant impact on the environmental gap between partner countries. The other factors affecting the latter are relatively the same as in the previous analysis.

6.5.5 Importance of the investor country

In international trade, a country typically trades with several partner countries around the world, but very often only a few dozen partner countries account for the lion's share of trade with the country. For example, [Krugman et al. \(2018\)](#) point out that even though the United States trades with many countries around the world when looking at their trade data statistics in 2015, only 15 countries accounted for 75% of the value of their trade. If a few partners play a significant role in a

²⁴In Table 6.C6, we show the results obtained with country-pair and time-fixes effects. They are similar to the ones of Table 6.C5.

host country's trade, we can assume that their FDI flows could have a substantial influence on the environment or play a key role in the host country's environmental policies. In this context, the FDI flows from these crucial partners can foster the convergence mechanism between them and the host country.

We explore this idea by re-estimating bilateral environmental convergence, the environmental convergence to the partner average, by taking into account the importance of partners. To do this, we first construct, for each host country, an indicator of partner rank based on total FDI flows received over the entire period under consideration. In other words, for each host country i , the rank indicator varies between 1 and P (total number of partner countries). For a host country i , the indicator is 1 for the first partner investor country (with the largest amount of total FDI flows), 2 for the second partner country, and so on up to P for the last partner country (with the lowest amount of total FDI flows). Then, we proceed to the estimation with subsamples composed of the p -first partners ($p = \{1, \dots, P\}$).

The results are presented in Figure 6.B5. In each of the subfigures, we have on the x-axis the p -first partners considered, and on the y-axis the estimated coefficients of FDI inflows. The non-statistically significant coefficients are shown in black. The statistically significant coefficients are presented in color: green at the 1% risk of error threshold, orange at the 5% risk of error threshold, and red at the 10% risk of error threshold. The subfigures on the left (6.B5a, 6.B5c, 6.B5e, 6.B5g, and 6.B5i) present the bilateral convergence and the subfigures on the right (6.B5b, 6.B5d, 6.B5f, 6.B5h, and 6.B5j) underlines the convergence to the average of the partners.

On each of the subfigures, the last coefficient corresponds to the coefficient of our baseline result, as it is estimated with all possible partners.

The results show that FDI from major investing partners significantly impacts the dynamics of environmental convergence. Analyzing the results for the convergence to the average, we note that FDI from the top five investors affects the environmental policies of host countries. This leads to environmental convergence (bilateral or to the average) in the OECD club of countries (when North-North FDI flows are considered) and divergence for North-South FDI partnerships. However, when examining the club of Southern countries and the South-North partnerships, the results are mixed. Specifically, in the Southern countries group, there is bilateral

environmental convergence with the two largest investor partners, but an enlarging environmental gap with respect to the average of the group of investor partners, in general. Overall, the higher the importance of FDI partners, as indicated by their share in the total FDI received by the country, the stronger their influence on the environmental performance of the host economy.

6.6 Robustness tests

The robustness of our results is tested along several lines: (1) using a time sub-sample, capturing the period before the Global Financial Crisis (GFC); (2) removing the country pairs for which the number of missing observations over the analyzed period is high (i.e. the criteria on which the data is removed will be explained below, in this section); (3) using alternative measures of the environmental performance in order to compute the environmental convergence; (4) normalizing the FDI by the host country's GDP, in order to take account of a certain size effect.

First, before conducting our robustness test related to time sub-spans, we get back to the descriptive statistics. Based on our descriptive analysis we note that: (i) the evolution of FDI has been impacted by the GFC (Figure 6.B1), (ii) the slope of EPI dynamics became almost flat after the GFC till 2012 (Figure 6.B2), and (iii) the speed of the convergence has changed (Figure 6.B3). The 2008 GFC thus seems to be a factor that has led to changes in the environmental landscape. Hence, we check the validity of our results before the crisis. Given the short time dimension of the post-crisis period, we prefer to stick to the pre-crisis data. Moreover, since the results in Figure 6.B5 summarize all of our estimates, we follow this pattern of results. Our findings are shown in Figure 6.B6. The results are robust. Moreover, for South-North partnerships, the results concerning the effects of FDI as a factor of environmental convergence become significant.

Second, we also test whether our results are robust to the variable used to measure environmental performance. Thus, we use four other indicators in order to compute the environmental convergence: Environmental Health Index, Ecosystem Vitality Index, CO2 per capita emission level, and NOX emissions (see respectively Figures 6.B8, 6.B9, 6.B10 and 6.B11 in Appendix). Although some coefficients become more significant when considering one environmental measure rather than

others, the importance of investor partner countries seems to condition the effects of FDI on environmental convergence. The other results remain valid despite some ambiguities for the Southern countries' group. Indeed, the hypothesis of environmental convergence is verified for most of the variables used to measure environmental performance, with the exception of the NOX variable for which we observe an environmental divergence.

Third, as there are missing observations and zero flows in our bilateral FDI data, concerns related to the data quality might be raised. As the FDI data is gathered from different sources, zero flows might mean either that there is missing data or no flows. To check the robustness of the results, we now treat the zeros in the FDI flows as missing values. Hence, we will keep, in this robustness test, only the country pairs for which the new number of missing observations in FDI flows exceeds 6 over the 13 periods that are studied. The sample size was reduced to 64445 observations. The results are presented in Figure 6.B7. They are similar to the ones of the baseline scenario.

Finally, we conduct a sensitivity test by allowing our FDI data to be expressed as a percentage of the GDP in the host country. The results are similar to the ones obtained initially.

6.7 Conclusion

In this study, we examine whether an environmental convergence emerges between FDI partner countries. We focus in particular on how FDI flows might affect the environmental convergence between the investor and host countries. We also identify the factors that may affect this relationship. To do so, we build a bilateral database with 8140 partner country peers, using data on 128 countries, over the period from 2000 to 2012. In order to take into account the heterogeneity of the types of flows or partnerships (North-North, North-South, South-North, South-South), we group the countries into two groups: Northern countries, including OECD countries, and Southern countries, gathering non-OECD countries.

The descriptive analysis reveals a homogeneity of environmental performance within the same group of countries, i.e., the group of Northern countries (OECD) for North-North FDI flows and the group of Southern countries for South-South

FDI, respectively. At the same time, a significant gap in environmental performance between the two groups is observed. Moreover, while Northern FDI partner countries appear to be converging in environmental performance through an average reduction in bilateral environmental gaps over time, Southern partner countries seem to be drifting apart in terms of environmental performance. It also seems that Northern and Southern partners were diverging prior to 2008, but afterward have started to converge. In terms of FDI analysis in general, our findings reiterate the idea of club investments over the period 2000 to 2012, i.e., in the latter year, countries preferred to invest more in partners belonging to the same club than in partners from a different club.

Our findings indicate that foreign direct investment (FDI) does not have a direct impact on environmental convergence, except for the case of FDI originating from major investor countries. Other factors such as economic development, industrialization, urbanization rate, energy use, or geographical proximity might directly influence environmental convergence. Threshold effects can be identified within this context in particular related to economic development or industrialization. However, under specific circumstances, FDI could potentially impact environmental convergence. This might depend on the nature of the FDI partnership being considered (e.g. North-North, North-South, South-North, and South-South).

Furthermore, as previously mentioned, our results also highlight that the more important the investors are, the stronger the influence of their FDI on the environmental performance of their host countries. In other words, the effect of FDI on environmental convergence also depends on the importance of the home country in the total FDI received by the host country. For example, FDI from the most important partner countries, especially the first five, encourages environmental convergence (or divergence), but this will depend on the type of FDI flow considered. These flows from the most important investor countries lead to a convergence (bilateral or to the average) in the group of OECD countries (North-North) and a divergence in the North-South partnerships. In contrast, within the group of Southern countries and in the South-North partnerships, the results are mixed. The robustness tests and the extensions considered consolidate our results.

APPENDIX

A Data description

Northern economies (35): Australia, Austria, Belgium, Canada, Switzerland, Chile, Cyprus, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hungary, Ireland, Israel, Italy, Japan, Korea South, Luxembourg, Mexico, Netherlands, Norway, New Zealand, Poland, Portugal, Slovak Republic, Slovenia, Sweden, Turkey, United States.

Southern economies (93): Angola, Albania, United Arab Emirates, Argentina, Azerbaijan, Benin, Bangladesh, Bulgaria, Bosnia, Belarus, Bolivia, Brazil, Brunei, Botswana, China, Ivory Coast, Cameroon, Congo Kinshasa, Congo (Rep.), Colombia, Costa Rica, Cuba, Dominican Republic, Algeria, Ecuador, Egypt, Eritrea, Ethiopia, Gabon, Georgia, Ghana, Guatemala, Honduras, Croatia, Haiti, Indonesia, India, Iran, Iraq, Jamaica, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Cambodia, Kuwait, Lebanon, Libya, Sri Lanka, Lithuania, Latvia, Morocco, Moldova, Macedonia, Malta, Myanmar (Burma), Mongolia, Mozambique, Malaysia, Namibia, Nigeria, Nicaragua, Nepal, Oman, Pakistan, Panama, Peru, Philippines, Paraguay, Qatar, Romania, Russia, Saudi Arabia, Sudan, Senegal, Singapore, El Salvador, Serbia, Togo, Thailand, Tajikistan, Turkmenistan, Tunisia, Tanzania, Ukraine, Uruguay, Uzbekistan, Venezuela, Vietnam, Yemen, South Africa, Zambia, Zimbabwe.

B Figures

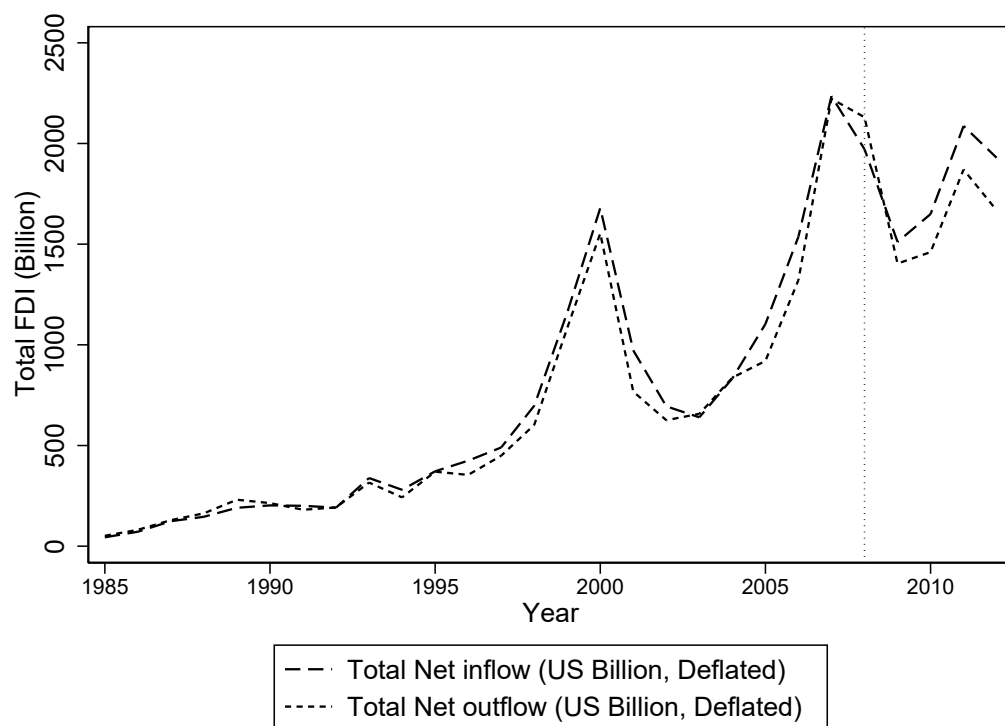


Figure 6.B1: FDI Evolution

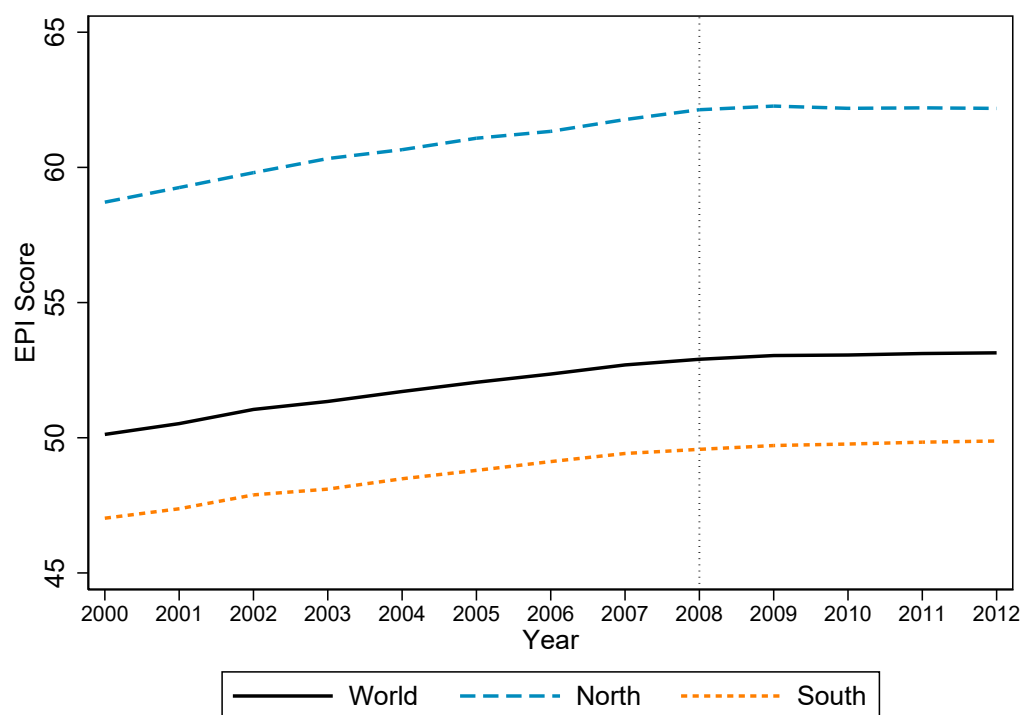


Figure 6.B2: Environmental Performance Index Evolution

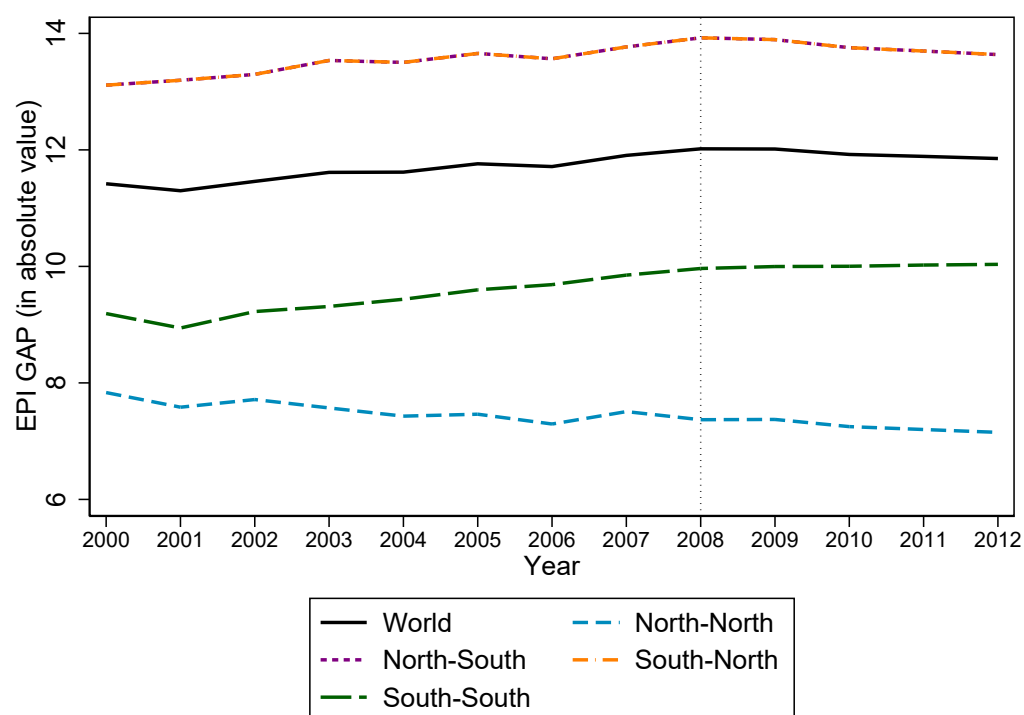


Figure 6.B3: Environmental gap

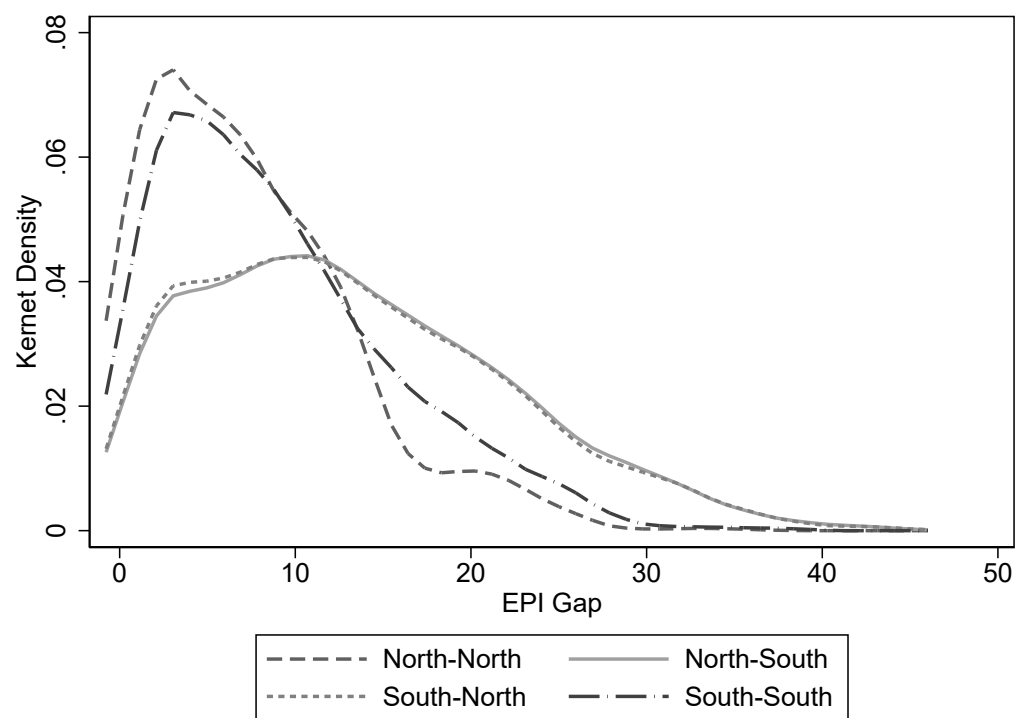


Figure 6.B4: Kernel density of environmental gap

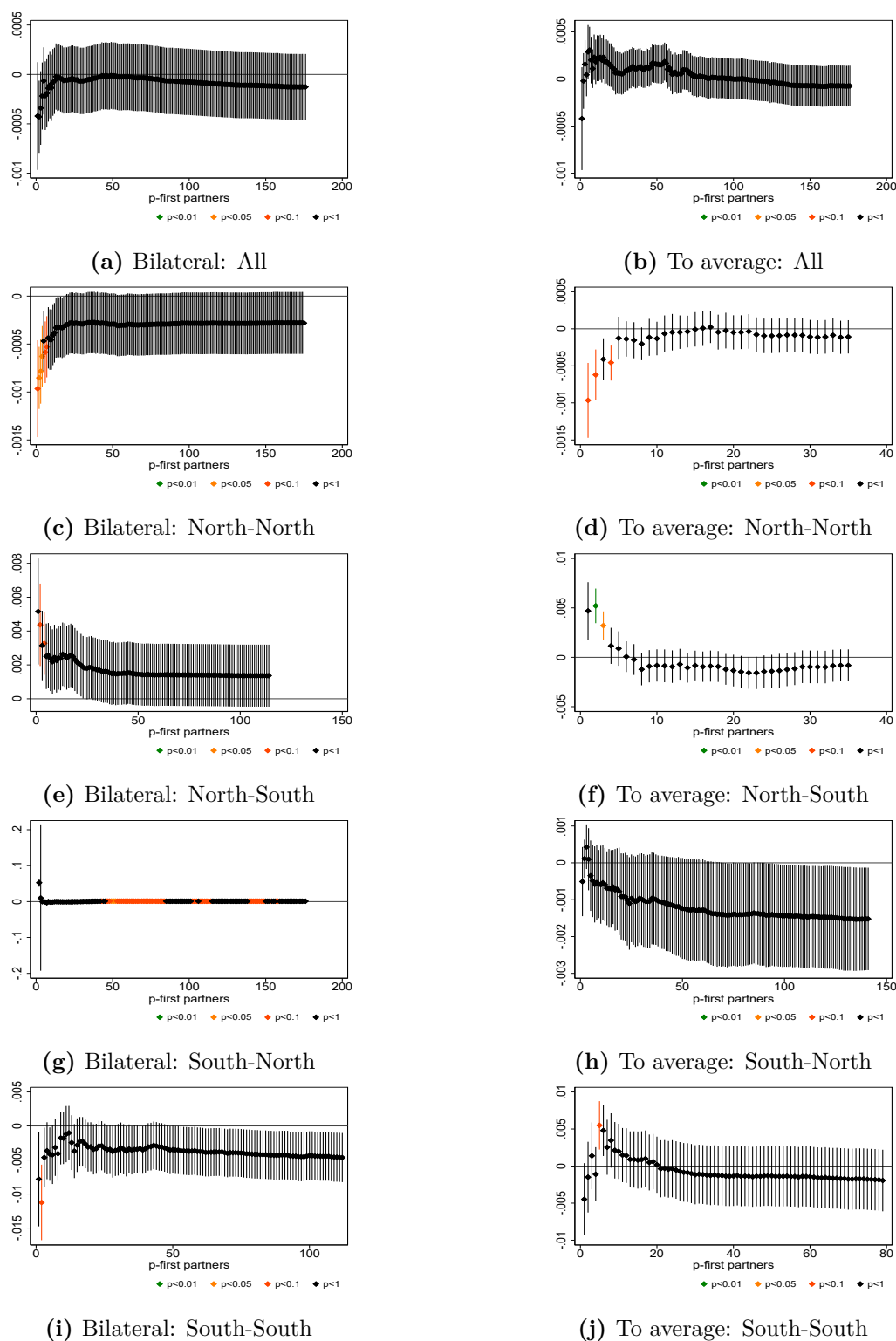


Figure 6.B5: Partners' importance in environmental convergence

Note: Sub-figure (a): FDI effects on bilateral environmental convergence between a host country and its investor partner. Sub-figure (b): FDI effects on the convergence of a host country to the average environmental performance of its investor partner countries. Sub-figure (c): FDI effects on the bilateral environmental convergence between a Northern host country and its Northern investor partner. Sub-figure (d): FDI effects on the convergence of a Northern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (e): FDI effects on the bilateral environmental convergence between a Southern host country and its Northern investor partner. Sub-figure (f): FDI impact on the convergence of a Southern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (g): FDI impact on the bilateral environmental convergence between a Northern host country and its Southern investor partner. Sub-figure (h): FDI impact on the convergence of a Northern host country to the average environmental performance of its Southern investor partner countries. Sub-figure (i): FDI impact on the bilateral environmental convergence between a Southern host country and its Southern investor partner. Sub-figure (j): FDI impact on the convergence of a Southern host country to the average environmental performance of its Southern investor partner countries.

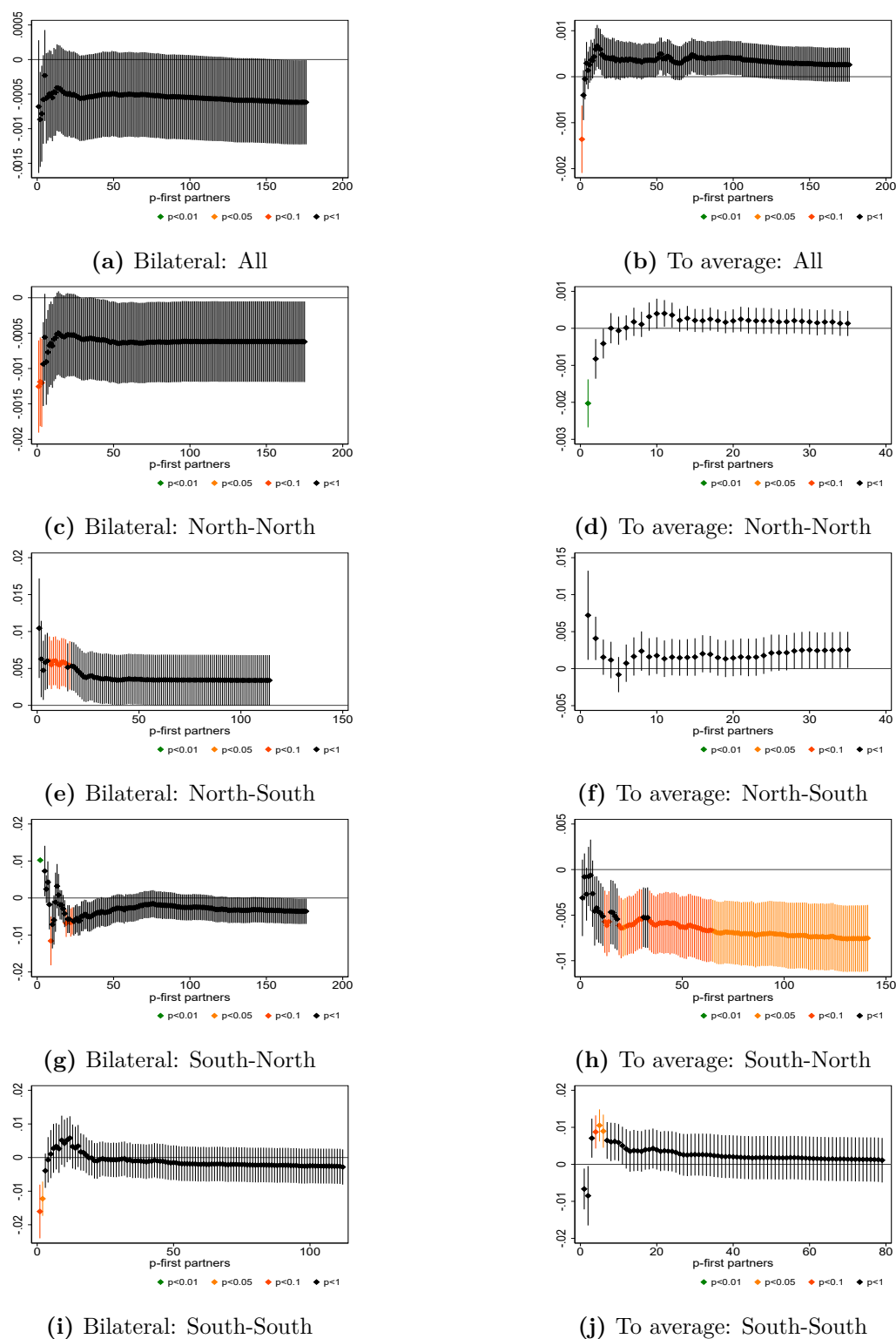


Figure 6.B6: Partners' importance in environmental convergence before the 2008 GFC

Note: Sub-figure (a): FDI effects on bilateral environmental convergence between a host country and its investor partner. Sub-figure (b): FDI effects on the convergence of a host country to the average environmental performance of its investor partner countries. Sub-figure (c): FDI effects on the bilateral environmental convergence between a Northern host country and its Northern investor partner. Sub-figure (d): FDI effects on the convergence of a Northern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (e): FDI effects on the bilateral environmental convergence between a Southern host country and its Northern investor partner. Sub-figure (f): FDI impact on the convergence of a Southern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (g): FDI impact on the bilateral environmental convergence between a Northern host country and its Southern investor partner. Sub-figure (h): FDI impact on the convergence of a Northern host country to the average environmental performance of its Southern investor partner countries. Sub-figure (i): FDI impact on the bilateral environmental convergence between a Southern host country and its Southern investor partner. Sub-figure (j): FDI impact on the convergence of a Southern host country to the average environmental performance of its Southern investor partner countries.

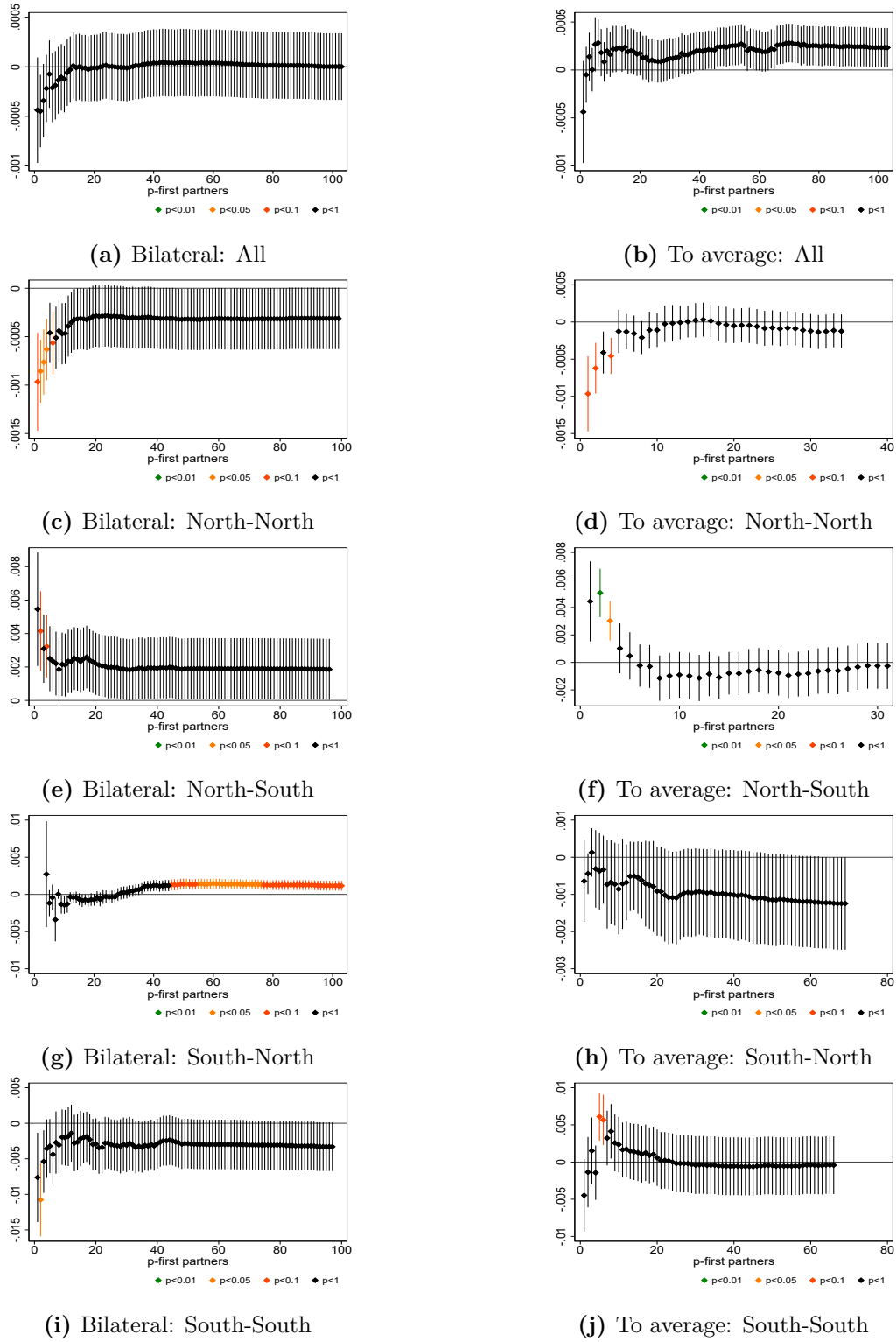


Figure 6.B7: Partners importance in environmental convergence with zero data processing

Note: Sub-figure (a): FDI effects on bilateral environmental convergence between a host country and its investor partner. Sub-figure (b): FDI effects on the convergence of a host country to the average environmental performance of its investor partner countries. Sub-figure (c): FDI effects on the bilateral environmental convergence between a Northern host country and its Northern investor partner. Sub-figure (d): FDI effects on the convergence of a Northern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (e): FDI effects on the bilateral environmental convergence between a Southern host country and its Northern investor partner. Sub-figure (f): FDI impact on the convergence of a Southern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (g): FDI impact on the bilateral environmental convergence between a Northern host country and its Southern investor partner. Sub-figure (h): FDI impact on the convergence of a Northern host country to the average environmental performance of its Southern investor partner countries. Sub-figure (i): FDI impact on the bilateral environmental convergence between a Southern host country and its Southern investor partner. Sub-figure (j): FDI impact on the convergence of a Southern host country to the average environmental performance of its Southern investor partner countries.

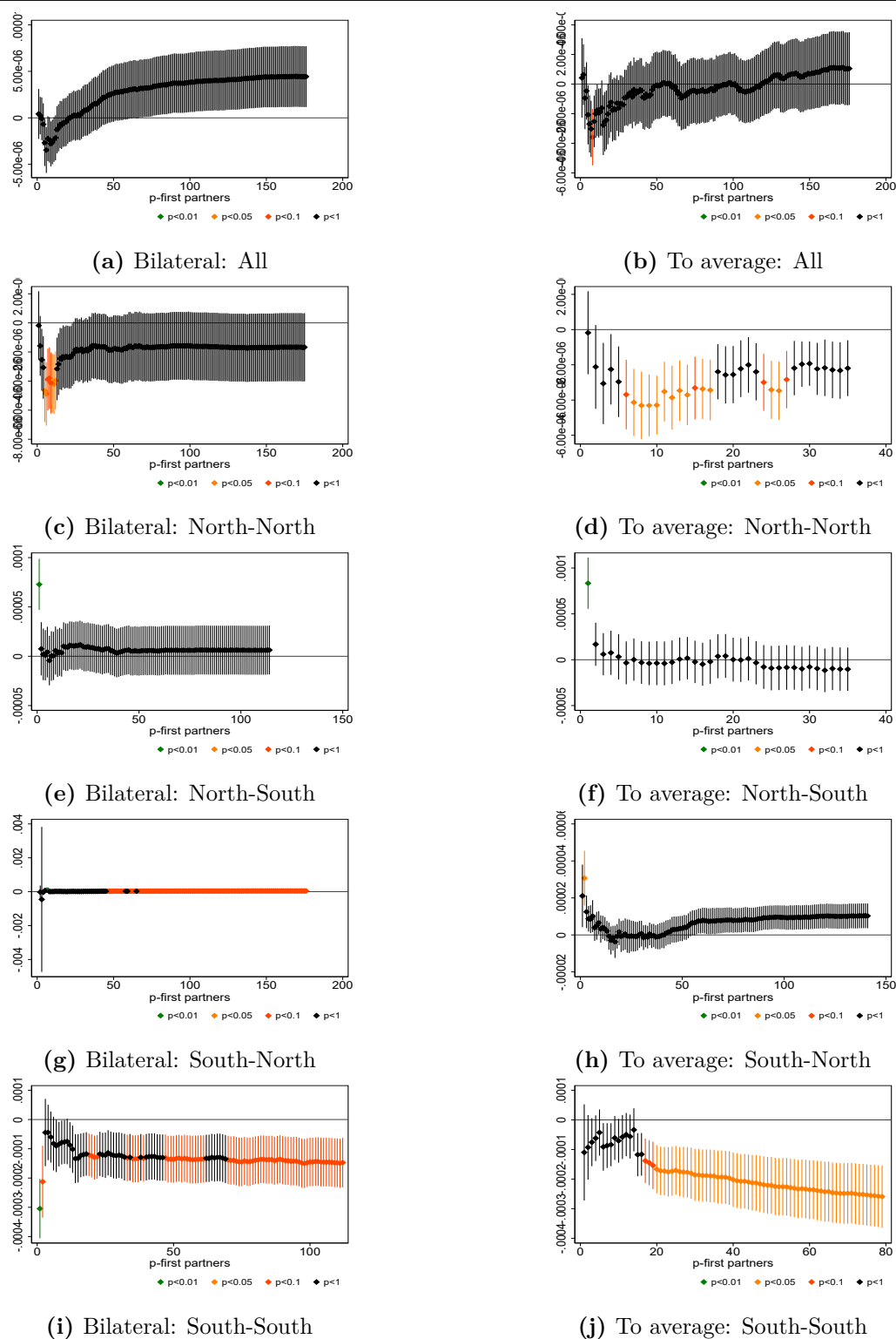


Figure 6.B8: Partners importance in environmental convergence using Environmental Health index

Note: Sub-figure (a): FDI effects on bilateral environmental convergence between a host country and its investor partner. Sub-figure (b): FDI effects on the convergence of a host country to the average environmental performance of its investor partner countries. Sub-figure (c): FDI effects on the bilateral environmental convergence between a Northern host country and its Northern investor partner. Sub-figure (d): FDI effects on the convergence of a Northern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (e): FDI effects on the bilateral environmental convergence between a Southern host country and its Northern investor partner. Sub-figure (f): FDI impact on the convergence of a Southern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (g): FDI impact on the bilateral environmental convergence between a Northern host country and its Southern investor partner. Sub-figure (h): FDI impact on the convergence of a Northern host country to the average environmental performance of its Southern investor partner countries. Sub-figure (i): FDI impact on the bilateral environmental convergence between a Southern host country and its Southern investor partner. Sub-figure (j): FDI impact on the convergence of a Southern host country to the average environmental performance of its Southern investor partner countries.

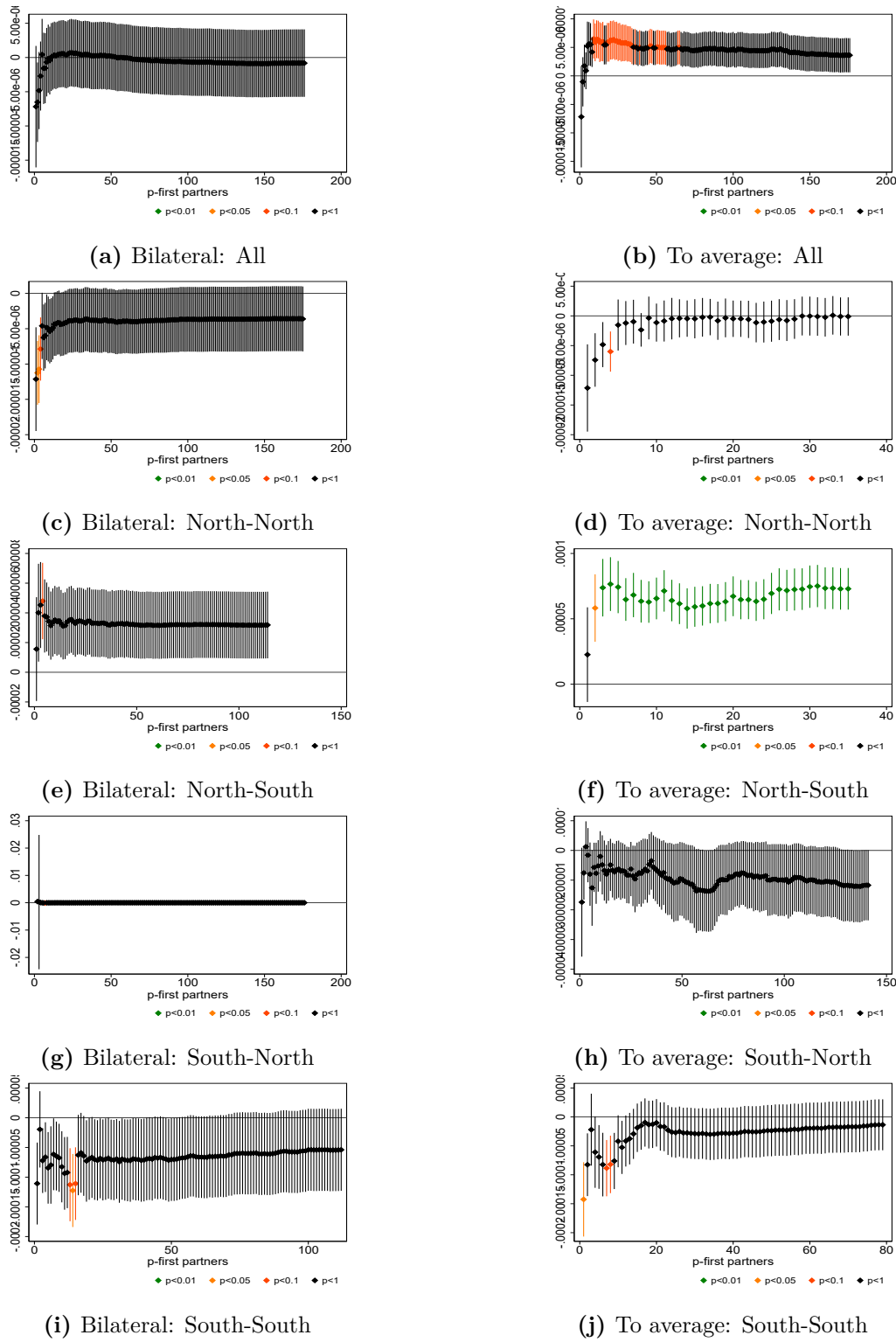


Figure 6.B9: Partners importance in environmental convergence using Ecosystem Vitality index

Note: Sub-figure (a): FDI effects on bilateral environmental convergence between a host country and its investor partner. Sub-figure (b): FDI effects on the convergence of a host country to the average environmental performance of its investor partner countries. Sub-figure (c): FDI effects on the bilateral environmental convergence between a Northern host country and its Northern investor partner. Sub-figure (d): FDI effects on the convergence of a Northern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (e): FDI effects on the bilateral environmental convergence between a Southern host country and its Northern investor partner. Sub-figure (f): FDI impact on the convergence of a Southern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (g): FDI impact on the bilateral environmental convergence between a Northern host country and its Southern investor partner. Sub-figure (h): FDI impact on the convergence of a Northern host country to the average environmental performance of its Southern investor partner countries. Sub-figure (i): FDI impact on the bilateral environmental convergence between a Southern host country and its Southern investor partner. Sub-figure (j): FDI impact on the convergence of a Southern host country to the average environmental performance of its Southern investor partner countries.

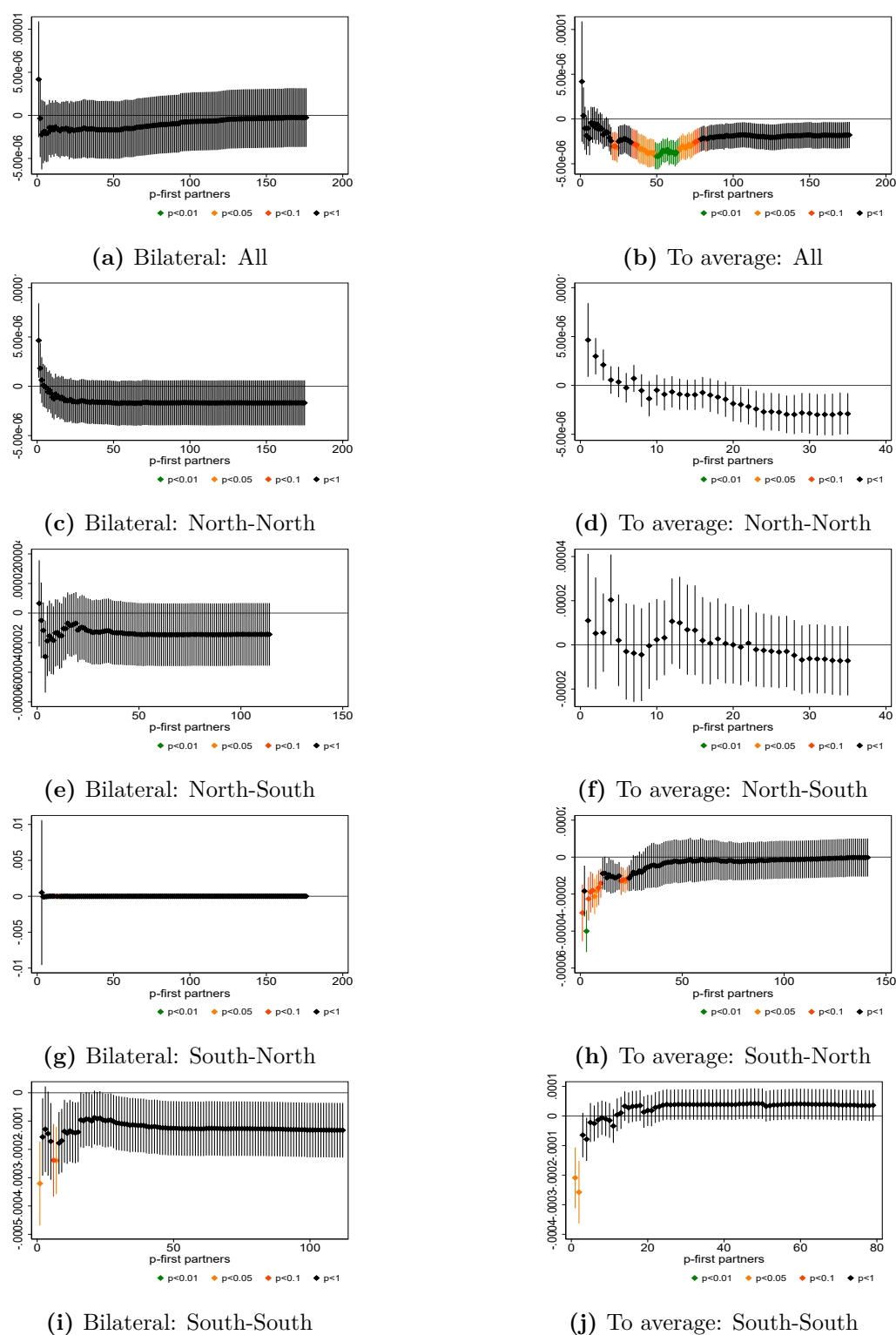


Figure 6.B10: Partners importance in environmental convergence using CO2 Emission per capita

Note: Sub-figure (a): FDI effects on bilateral environmental convergence between a host country and its investor partner. Sub-figure (b): FDI effects on the convergence of a host country to the average environmental performance of its investor partner countries. Sub-figure (c): FDI effects on the bilateral environmental convergence between a Northern host country and its Northern investor partner. Sub-figure (d): FDI effects on the convergence of a Northern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (e): FDI effects on the bilateral environmental convergence between a Southern host country and its Northern investor partner. Sub-figure (f): FDI impact on the convergence of a Southern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (g): FDI impact on the bilateral environmental convergence between a Northern host country and its Southern investor partner. Sub-figure (h): FDI impact on the convergence of a Northern host country to the average environmental performance of its Southern investor partner countries. Sub-figure (i): FDI impact on the bilateral environmental convergence between a Southern host country and its Southern investor partner. Sub-figure (j): FDI impact on the convergence of a Southern host country to the average environmental performance of its Southern investor partner countries.

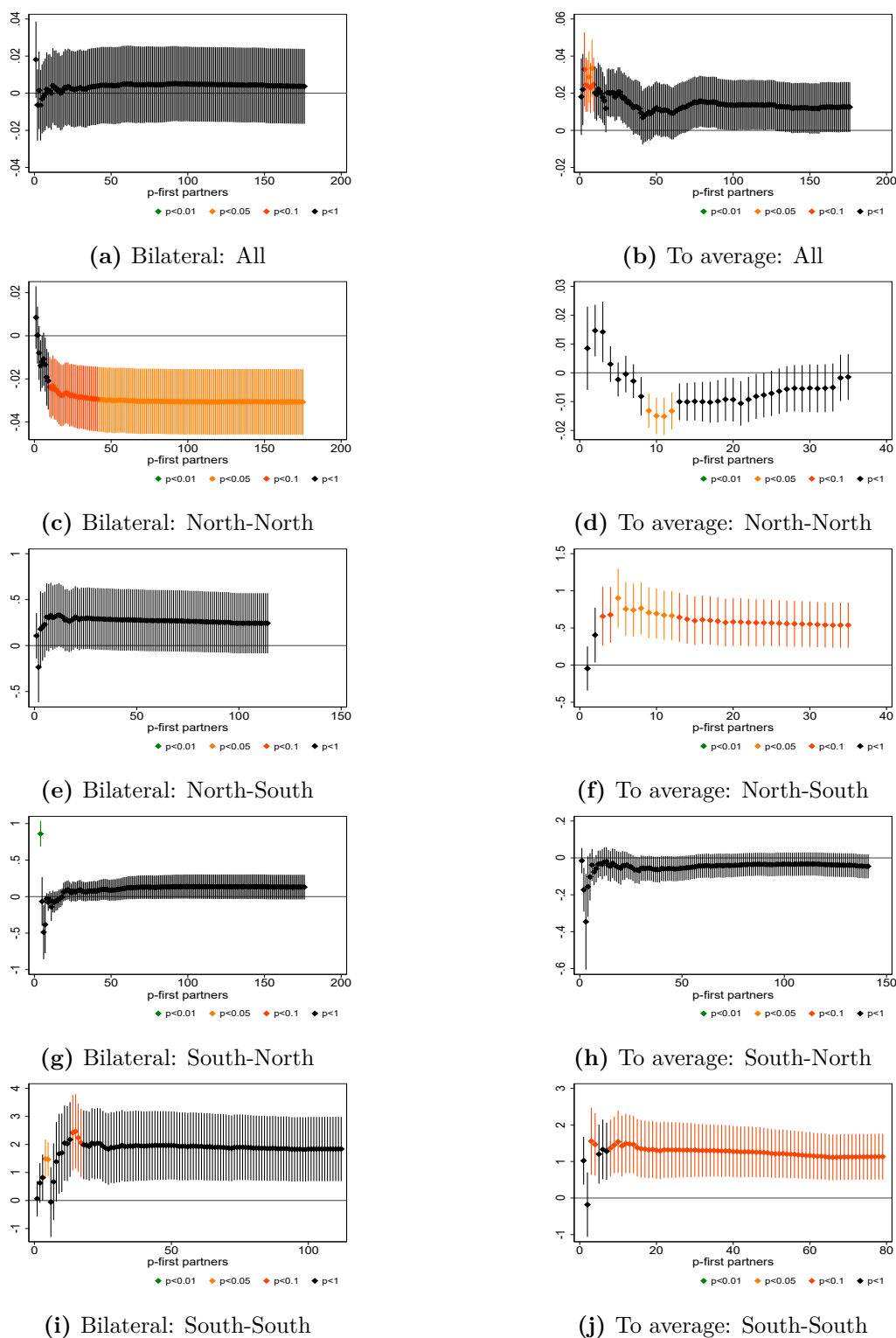


Figure 6.B11: Partners importance in environmental convergence using NOX emission

Note: Sub-figure (a): FDI effects on bilateral environmental convergence between a host country and its investor partner. Sub-figure (b): FDI effects on the convergence of a host country to the average environmental performance of its investor partner countries. Sub-figure (c): FDI effects on the bilateral environmental convergence between a Northern host country and its Northern investor partner. Sub-figure (d): FDI effects on the convergence of a Northern host country to the average environmental performance of its Northern investor partner countries. Sub-figure (e): FDI effects on the bilateral environmental convergence between a Southern host country and its Northern investor partner. Sub-figure (f): FDI impact on the convergence of a Southern host country to the average environmental performance of its Southern investor partner countries. Sub-figure (g): FDI impact on the bilateral environmental convergence between a Northern host country and its Southern investor partner. Sub-figure (h): FDI impact on the convergence of a Northern host country to the average environmental performance of its Southern investor partner countries. Sub-figure (i): FDI impact on the bilateral environmental convergence between a Southern host country and its Southern investor partner. Sub-figure (j): FDI impact on the convergence of a Southern host country to the average environmental performance of its Southern investor partner countries.

C Tables

Table 6.C1: Descriptive statistics

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
EPI Gap (Absolute Value)	90,067	11.76	8.414	0	45.25
... of North-North	15,358	7.413	5.819	0	35.70
... of North-South	31,187	13.40	8.760	0.000137	45.25
... of South-North	32,358	13.21	8.690	0.000137	45.25
... of South-South	11,164	8.999	6.637	0.000798	37.63
FDI	86,272	163.9	1,920	-59,483	117,839
... of North-North	14,643	712.7	4,473	-59,483	117,839
... of North-South	25,216	83.76	620.7	-15,113	21,416
... of South-North	36,401	22.37	478.8	-8,852	66,836
... of South-South	10,012	77.97	418.4	-1,684	8,514
Host: GDP per capita	105,231	23,946	22,550	194.9	111,968
Host: Manufacturing	103,684	15.49	8.263	0.908	161.5
Host: Urban population rate	105,231	68.70	18.39	13.40	100
Host: Energy use	105,231	3,356	2,859	143.1	22,120
Home: GDP per capita	103,249	20,253	22,033	194.9	111,968
Home: Manufacturing	99,143	14.61	8.476	0.138	161.5
Home: Urban population rate	104,286	62.93	21.79	8.246	100
Home: Energy use	93,204	3,178	2,909	9.548	22,120
Contiguity	102,728	0.0364	0.187	0	1
Common language	102,728	0.106	0.308	0	1
Colonial relationship	102,728	0.0294	0.169	0	1
Common colonizer post 1945	102,728	0.0182	0.134	0	1
Currently in colonial relationship	102,728	0.000633	0.0251	0	1
Colonial relationship post 1945	102,728	0.0148	0.121	0	1
Same country	102,728	0.0143	0.119	0	1
Landlocked (Home and Host)	105,241	0.340	0.532	0	2
Distance (Log)	102,728	8.512	0.919	2.951	9.891

Table 6.C2: Model specification

VARIABLES	(1)	(2)	(3)	(4)	(5)
FDI (Lag)	-0.0091*** [0.0021]	-0.0091*** [0.0021]	-0.0055** [0.0023]	-0.0046** [0.0022]	-0.00013 [0.00033]
Host: GDP per capita (Lag)	-0.0043*** [0.0015]	-0.0043*** [0.0015]	0.013*** [0.0028]	0.0081*** [0.0022]	0.0092*** [0.0013]
Host: GDP per capita (Square, Lag)	7.4e-08*** [1.6e-08]	7.4e-08*** [1.6e-08]	-7.6e-08*** [2.2e-08]	-6.4e-08*** [1.8e-08]	-1.2e-07*** [1.0e-08]
Host: Manufacturing (Lag)	-16.3*** [2.21]	-16.2*** [2.25]	-11.3*** [1.75]	-8.00*** [1.45]	-6.36*** [0.79]
Host: Manufacturing (Square, Lag)	0.15*** [0.020]	0.15*** [0.020]	0.073*** [0.014]	0.057*** [0.013]	0.025*** [0.0046]
Host: Urban population rate (Lag)	-2.24 [3.14]	-2.11 [3.14]	-25.4*** [6.90]	-12.5** [5.21]	-2.26 [2.98]
Host: Urban population rate (Square, Lag)	-0.035 [0.025]	-0.036 [0.025]	0.090* [0.052]	0.016 [0.039]	-0.018 [0.022]
Host: Energy use (Lag)	0.021*** [0.0053]	0.021*** [0.0053]	0.029*** [0.0053]	0.023*** [0.0048]	0.0096*** [0.0019]
Home: GDP per capita (Lag)	-0.0038** [0.0015]	-0.0037** [0.0015]	-0.0050*** [0.0013]	0.0020 [0.0022]	0.0078*** [0.0012]
Home: GDP per capita (Square, Lag)	8.6e-08*** [1.6e-08]	8.5e-08*** [1.6e-08]	9.5e-08*** [1.4e-08]	-3.5e-08* [1.8e-08]	-1.1e-07*** [1.0e-08]
Home: Manufacturing (Lag)	-13.3*** [2.19]	-13.2*** [2.22]	-13.7*** [2.02]	-7.56*** [1.53]	-7.09*** [0.80]
Home: Manufacturing (Square, Lag)	0.12*** [0.021]	0.12*** [0.021]	0.12*** [0.018]	0.038*** [0.013]	0.025*** [0.0047]
Home: Urban population rate (Lag)	1.23 [3.06]	1.32 [3.06]	1.91 [2.77]	-2.79 [5.00]	-0.10 [2.76]
Home: Urban population rate (Square, Lag)	-0.056** [0.024]	-0.057** [0.024]	-0.058*** [0.021]	-0.031 [0.037]	-0.027 [0.021]
Home: Energy use (Lag)	0.0089* [0.0052]	0.0088* [0.0052]	0.0051 [0.0045]	0.020*** [0.0049]	0.0091*** [0.0019]
Contiguity	-327*** [43.4]	-327*** [43.4]	-299*** [49.5]	-264*** [55.6]	
Common language	-171*** [30.9]	-171*** [30.9]	-129*** [30.2]	-44.8 [28.7]	
Colonial relationship	59.8 [74.8]	61.0 [74.8]	12.6 [73.3]	-41.4 [70.2]	
Common colonizer post 1945	46.1 [77.5]	46.5 [77.5]	-69.4 [85.0]	-223** [90.7]	
Currently in colonial relationship	-481 [313]	-484 [314]	-126 [266]	320 [219]	
Colonial relationship post 1945	398*** [115]	397*** [115]	305*** [106]	145 [97.5]	
Same country	-107 [71.3]	-107 [71.2]	66.4 [72.0]	230*** [70.5]	
Landlocked (Home and Host)	121*** [22.3]	121*** [22.3]	145*** [27.1]	108 [179]	
Distance (Log)	40.7*** [11.2]	40.4*** [11.2]	98.0*** [11.6]	157*** [12.2]	
Constant	1,607*** [184]	1,573*** [185]	2,023*** [319]	1,288*** [351]	1,501*** [154]
Observations	66,535	66,535	66,535	66,535	66,535
R-squared	0.093	0.094	0.326	0.581	0.047
Year FE	No	Yes	Yes	Yes	Yes
Host FE	No	No	Yes	Yes	No
Home FE	No	No	No	Yes	No
Country-pair FE	No	Yes	No	No	Yes
RMSE	790.189	790.157	681.784	538.486	113.597
Number of id					6,696

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 6.C3: Effect of FDI on convergence - Heterogeneity by type of flow

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Without partner country pair fixed effect					With partner country pair fixed effect				
	Full sample	South-South	South-North	North-South	North-North	Full sample	South-South	South-North	North-South	North-North
FDI (Lag)	-0.032 [0.030]	0.0093 [0.020]	0.0010 [0.0029]	0.0036 [0.0054]	0.0019 [0.0013]	-0.0026 [0.0045]	-0.0046 [0.0036]	0.0011 [0.00071]	0.0014 [0.0018]	-0.00028 [0.00032]
$N_i \times$ FDI (Lag)	0.020** [0.0089]					0.0011 [0.00070]				
$N_j \times$ FDI (Lag)	0.043*** [0.014]					0.0010 [0.0018]				
$N_i \times N_j \times$ FDI (Lag)	-0.0065*** [0.0024]					-0.00019 [0.00035]				
Host: GDP per capita (Lag)	0.0080*** [0.0023]	0.021 [0.014]	0.014*** [0.0029]	0.0025 [0.0064]	0.012*** [0.0033]	0.0092*** [0.0013]	0.012 [0.0081]	0.019*** [0.0025]	-0.0083* [0.0043]	0.014*** [0.0029]
Host: GDP per capita (Square, Lag)	-6.4e-08*** [1.8e-08]	-2.4e-07 [1.6e-07]	-1.1e-07*** [1.7e-08]	-3.1e-08 [6.8e-08]	-1.3e-07*** [2.4e-08]	-1.2e-07*** [1.0e-08]	-1.4e-07 [9.0e-08]	-1.5e-07*** [1.5e-08]	6.9e-08 [4.8e-08]	-1.4e-07*** [1.8e-08]
Host: Manufacturing (Lag)	-7.94*** [1.46]	-4.91 [3.13]	-28.8*** [7.08]	-5.85*** [1.25]	-38.6*** [7.37]	-6.36*** [0.79]	-1.60 [2.08]	-29.9*** [5.72]	-5.14*** [0.92]	-40.9*** [6.50]
Host: Manufacturing (Square, Lag)	0.056*** [0.013]	0.025 [0.023]	0.47*** [0.16]	0.023*** [0.0078]	0.69*** [0.18]	0.025*** [0.0046]	0.014 [0.013]	0.48*** [0.14]	0.023*** [0.0052]	0.70*** [0.16]
Host: Urban population rate (Lag)	-12.8** [5.22]	13.7 [13.6]	15.4 [23.2]	-13.4** [5.34]	-90.5*** [15.8]	-2.26 [2.98]	1.97 [8.25]	49.7*** [17.9]	-18.6*** [4.10]	-76.0*** [14.1]
Host: Urban population rate (Square, Lag)	0.017 [0.039]	-0.18 [0.12]	-0.17 [0.14]	0.089* [0.048]	0.55*** [0.097]	-0.018 [0.022]	-0.12* [0.072]	-0.35*** [0.11]	0.10*** [0.035]	0.45*** [0.088]
Host: Energy use (Lag)	0.023*** [0.0048]	-0.0079 [0.014]	0.020*** [0.0051]	0.025*** [0.0072]	0.0094** [0.0043]	0.0096*** [0.0019]	0.012* [0.0073]	0.017*** [0.0029]	0.029*** [0.0048]	0.0061** [0.0031]
Home: GDP per capita (Lag)	0.0021 [0.0022]	0.022* [0.013]	-0.0077 [0.0069]	0.0048* [0.0027]	0.010*** [0.0034]	0.0078*** [0.0012]	0.011 [0.0078]	-0.011** [0.0043]	0.012*** [0.0022]	0.012*** [0.0028]
Home: GDP per capita (Square, Lag)	-3.7e-08** [1.8e-08]	-2.4e-07 [1.5e-07]	7.8e-08 [7.4e-08]	-7.4e-08*** [1.6e-08]	-1.2e-07*** [2.4e-08]	-1.1e-07*** [1.0e-08]	-1.3e-07 [8.6e-08]	1.0e-07*** [4.8e-08]	-1.3e-07*** [1.4e-08]	-1.4e-07*** [1.8e-08]
Home: Manufacturing (Lag)	-7.64*** [1.53]	0.71 [3.50]	-5.84*** [1.41]	-28.7*** [6.71]	-33.5*** [7.40]	-7.10*** [0.80]	-0.22 [2.11]	-5.24*** [5.61]	-35.8*** [5.61]	-37.8*** [6.58]
Home: Manufacturing (Square, Lag)	0.038*** [0.013]	-0.018 [0.026]	0.019** [0.0093]	0.33*** [0.16]	0.50*** [0.18]	0.025*** [0.0047]	0.0051 [0.013]	0.020*** [0.0054]	0.49*** [0.13]	0.60*** [0.16]
Home: Urban population rate (Lag)	-1.61 [4.98]	17.1 [12.1]	-6.49 [5.98]	17.7 [20.4]	-80.4*** [15.8]	-0.064 [2.76]	1.10 [7.26]	-16.3*** [4.08]	42.8** [16.8]	-75.8*** [14.2]
Home: Urban population rate (Square, Lag)	-0.040 [0.037]	-0.20* [0.11]	0.020 [0.053]	-0.15 [0.12]	0.49*** [0.097]	-0.028 [0.020]	-0.100 [0.066]	0.081** [0.035]	-0.29*** [0.10]	0.46*** [0.088]
Home: Energy use (Lag)	0.021*** [0.0049]	-0.0041 [0.013]	0.021*** [0.0078]	0.023*** [0.0051]	0.0041 [0.0040]	0.0091*** [0.0019]	0.011 [0.0077]	0.027*** [0.0051]	0.020*** [0.0029]	0.0051 [0.0032]
Contiguity	-258*** [55.6]	-159** [63.5]	-16.3 [140]	51.0 [149]	-135** [59.5]					
Common language	-45.5 [28.7]	18.8 [71.5]	166*** [38.7]	25.5 [28.9]	-177*** [53.1]					
Colonial relationship	-42.3 [70.2]	13.9 [238]	-157 [141]	-87.7 [140]	215*** [64.8]					
Common colonizer post 1945	-221** [90.7]	159 [98.3]	131 [135]	97.2 [141]	-185* [99.2]					
Currently in colonial relationship	324 [219]				-561*** [138]					
Colonial relationship post 1945	145 [97.1]	-11.1 [270]	104 [135]	125 [131]	300*** [103]					
Same country	226*** [70.5]	51.2 [73.3]	-60.3 [122]	43.3 [122]	274*** [80.3]					
Landlocked (Home and Host)	-529*** [121]	647*** [77.4]	660*** [230]	775*** [121]	852*** [232]					
Distance (Log)	156*** [12.2]	87.2** [39.2]	23.5 [26.4]	79.5*** [20.8]	153*** [23.8]					
Constant	1,356*** [362]	-924 [681]	2,014*** [727]	922 [947]	6,096*** [959]	1,499*** [154]	1,379*** [297]	110 [723]	658 [685]	7,375*** [868]
Observations	66,535	7,633	22,200	22,413	14,289	66,535	7,633	22,200	22,413	14,289
R-squared	0.581	0.536	0.799	0.841	0.532	0.047	0.109	0.075	0.079	0.118
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Host FE	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
Home FE	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
Country-pair FE	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
RMSE	538.152	469.354	389.266	349.574	400.490	113.598	107.757	111.203	109.765	114.663
Number of id						6,696	828	2,331	2,344	1,193

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 6.C4: Effect of FDI on convergence - Heterogeneity by home and host country

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Without partner country pair fixed effect				With partner country pair fixed effect			
	Host: South	Host: North	Home: South	Home: North	Host: South	Host: North	Home: South	Home: North
FDI (Lag)	0.0083 [0.0079]	0.00080 [0.0018]	0.0012 [0.0040]	-0.00073 [0.0017]	0.000094 [0.0017]	-0.00023 [0.00033]	0.00036 [0.00094]	-0.000094 [0.00034]
Host: GDP per capita (Lag)	0.013* [0.0068]	0.0078*** [0.0026]	0.010*** [0.0026]	0.0084*** [0.0026]	-0.0032 [0.0039]	0.016*** [0.0020]	0.013*** [0.0018]	0.0062*** [0.0018]
Host: GDP per capita (Square, Lag)	-1.3e-07* [7.5e-08]	-7.2e-08*** [1.6e-08]	-8.9e-08*** [1.8e-08]	-1.2e-07*** [2.5e-08]	1.5e-08 [4.3e-08]	-1.5e-07*** [1.2e-08]	-1.3e-07*** [1.3e-08]	-1.1e-07*** [1.6e-08]
Host: Manufacturing (Lag)	-4.34*** [1.42]	-19.2*** [5.82]	-10.3*** [2.55]	-6.51*** [1.30]	-4.36*** [0.85]	-31.3*** [4.44]	-8.70*** [1.68]	-5.82*** [0.89]
Host: Manufacturing (Square, Lag)	0.028*** [0.010]	0.30** [0.14]	0.056** [0.023]	0.023** [0.0090]	0.019*** [0.0049]	0.51*** [0.11]	0.056*** [0.012]	0.021*** [0.0049]
Host: Urban population rate (Lag)	-2.12 [6.67]	-71.0*** [16.7]	-4.43 [9.96]	-3.11 [4.94]	-15.2*** [3.82]	-13.5 [12.7]	13.1** [5.99]	-4.02 [3.37]
Host: Urban population rate (Square, Lag)	-0.0011 [0.057]	0.37*** [0.10]	-0.060 [0.070]	0.0059 [0.037]	0.067** [0.032]	0.063 [0.080]	-0.13*** [0.042]	-0.00060 [0.025]
Host: Energy use (Lag)	0.012* [0.0069]	0.026*** [0.0044]	0.0084 [0.0056]	0.014*** [0.0041]	0.025*** [0.0041]	0.011*** [0.0024]	0.0098*** [0.0025]	0.012*** [0.0028]
Home: GDP per capita (Lag)	0.0059** [0.0025]	0.0032 [0.0029]	0.0041 [0.0064]	-0.0012 [0.0025]	0.010*** [0.0017]	0.0050*** [0.0018]	-0.0042 [0.0039]	0.011*** [0.0018]
Home: GDP per capita (Square, Lag)	-6.5e-08*** [1.8e-08]	-9.9e-08*** [2.6e-08]	-3.3e-08 [7.1e-08]	-3.2e-08*** [1.6e-08]	-1.2e-07*** [1.3e-08]	-1.0e-07*** [1.6e-08]	3.3e-08 [4.3e-08]	-1.3e-07*** [1.1e-08]
Home: Manufacturing (Lag)	-10.3*** [2.89]	-5.92*** [1.43]	-3.56** [1.45]	-18.0*** [5.58]	-11.6*** [1.73]	-5.87*** [0.90]	-4.04*** [0.86]	-32.7*** [4.40]
Home: Manufacturing (Square, Lag)	0.026 [0.028]	0.014 [0.011]	0.013 [0.0099]	0.11 [0.14]	0.071*** [0.013]	0.018*** [0.0051]	0.014*** [0.0051]	0.45*** [0.11]
Home: Urban population rate (Lag)	-0.63 [8.32]	10.2* [5.53]	1.43 [6.09]	-65.4*** [15.5]	11.7** [5.04]	-1.55 [3.30]	-12.7*** [3.63]	-14.2 [12.4]
Home: Urban population rate (Square, Lag)	-0.055 [0.059]	-0.095** [0.041]	-0.048 [0.054]	0.37*** [0.096]	-0.11*** [0.036]	-0.017 [0.025]	0.047 [0.032]	0.073 [0.077]
Home: Energy use (Lag)	0.012* [0.0060]	0.0079* [0.0042]	0.013* [0.0069]	0.023*** [0.0042]	0.011*** [0.0025]	0.010*** [0.0029]	0.023*** [0.0043]	0.012*** [0.0024]
Contiguity	-156*** [60.2]	-221*** [71.7]	-160*** [57.9]	-184*** [71.0]				
Common language	-5.47 [33.7]	8.37 [38.3]	140*** [32.8]	-85.3** [34.1]				
Colonial relationship	-96.2 [122]	24.5 [80.3]	-142 [124]	41.1 [82.4]				
Common colonizer post 1945	75.6 [89.0]	44.9 [149]	79.4 [88.4]	23.9 [150]				
Currently in colonial relationship		-102 [258]		-1.44 [166]				
Colonial relationship post 1945	61.9 [136]	211** [93.6]	44.8 [141]	224** [89.8]				
Same country	2.43 [76.9]	237*** [81.9]	-74.3 [76.2]	319*** [85.0]				
Landlocked (Home and Host)	-2.211*** [554]	574** [256]	-759* [390]	-4.16 [209]				
Distance (Log)	64.5*** [19.5]	157*** [16.2]	20.2 [19.1]	171*** [15.5]				
Constant	1,643*** [390]	2,854*** [676]	621 [472]	2,692*** [617]	1,617*** [222]	1,970*** [519]	1,430*** [247]	2,222*** [510]
Observations	30,046	36,489	29,833	36,702	30,046	36,489	29,833	36,702
R-squared	0.699	0.671	0.706	0.731	0.065	0.058	0.066	0.062
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Host FE	Yes	Yes	Yes	Yes	No	No	No	No
Home FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-pair FE	No	No	No	No	Yes	Yes	Yes	Yes
RMSE	466.584	465.602	455.865	427.314	110.501	114.666	111.326	113.700
Number of id					3,172	3,524	3,159	3,537

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 6.C5: Convergence to the partner average

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Heterogeneity								
	Full sample	Host country		Home country		Club convergence		Non-club Convergence	
VARIABLES	Convergence of host country to average of partner countries	Convergence of Southern host country to average of partner countries	Convergence of Northern host country to average of partner countries	Convergence of host country to average of Northern partner countries	Convergence of host country to average of Southern partner countries	Convergence of Northern host country to average of Northern partner countries	Convergence of Southern host country to average of Southern partner countries	Convergence of Northern host country to average of Northern partner countries	Convergence of Southern host country to average of Southern partner countries
FDI (Lag)	-0.000046 [0.00016]	0.00098 [0.00069]	-0.000098 [0.00017]	0.00019 [0.00016]	-0.00019 [0.00013]	-0.000069 [0.00017]	-0.00036 [0.00031]	-0.00015 [0.00012]	-0.00013 [0.00010]
Host: GDP per capita (Lag)	0.015*** [0.00081]	0.0021 [0.0031]	0.025*** [0.0012]	0.011*** [0.0012]	0.016*** [0.0012]	0.020*** [0.0019]	0.021*** [0.0069]	0.026*** [0.0015]	-0.00051 [0.0036]
Host: GDP per capita (Square, Lag)	-1.3e-07*** [6.2e-09]	-2.6e-08 [3.3e-08]	-1.7e-07*** [6.7e-09]	-1.4e-07*** [1.0e-08]	-1.3e-07*** [7.7e-09]	-1.9e-07*** [1.1e-08]	-2.5e-07*** [7.4e-08]	-1.6e-07*** [7.7e-09]	-3.3e-09 [3.9e-08]
Host: Manufacturing (Lag)	-4.57*** [0.54]	-5.60*** [0.56]	-0.13 [3.37]	-6.40*** [0.67]	-6.52*** [1.22]	-63.7*** [5.33]	-4.95*** [1.52]	-19.9*** [4.39]	-4.66*** [0.68]
Host: Manufacturing (Square, Lag)	0.014*** [0.0027]	0.023*** [0.0030]	-0.16*** [0.074]	0.020*** [0.0034]	0.045*** [0.011]	1.14*** [0.13]	0.036*** [0.011]	0.38*** [0.096]	0.015*** [0.0036]
Host: Urban population rate (Lag)	4.95*** [1.51]	-1.25 [2.17]	-36.3*** [7.24]	-5.62*** [2.63]	21.4*** [4.29]	-130*** [7.09]	8.27 [6.87]	71.1*** [12.5]	-16.8*** [3.51]
Host: Urban population rate (Square, Lag)	-0.063*** [0.011]	-0.031 [0.020]	0.22*** [0.044]	-0.020 [0.018]	-0.17*** [0.028]	0.75*** [0.041]	-0.11*** [0.057]	-0.47*** [0.077]	0.084*** [0.028]
Host: Energy use (Lag)	0.0027*** [0.0010]	0.019*** [0.0032]	-0.0029** [0.0013]	0.0046*** [0.0017]	0.0056*** [0.0015]	0.0048*** [0.0015]	0.010* [0.0056]	0.0091*** [0.0020]	0.016*** [0.0038]
Home: GDP per capita (Lag)	0.00099 [0.00096]	0.000038 [0.0014]	0.0012 [0.0013]	0.000079 [0.0015]	0.0065** [0.0026]	0.00011 [0.0020]	0.012** [0.0050]	0.0034 [0.0029]	0.00043 [0.0019]
Home: GDP per capita (Square, Lag)	-7.2e-09 [7.6e-09]	-2.7e-09 [9.5e-09]	-1.4e-08 [1.2e-08]	-1.5e-09 [9.0e-09]	-6.7e-08** [3.0e-08]	-9.7e-10 [1.2e-08]	-1.2e-07** [5.9e-08]	-3.7e-08 [3.2e-08]	-3.1e-09 [1.1e-08]
Home: Manufacturing (Lag)	-0.061 [0.52]	0.20 [1.02]	0.10 [0.59]	0.57 [3.10]	-0.36 [0.61]	1.24 [3.95]	-1.24 [1.55]	-0.14 [0.64]	-2.62 [4.17]
Home: Manufacturing (Square, Lag)	0.00011 [0.0032]	-0.0044 [0.0061]	-0.00068 [0.0035]	-0.018 [0.081]	0.0022 [0.0037]	-0.030 [0.11]	0.0056 [0.0093]	0.0011 [0.0038]	0.049 [0.11]
Home: Urban population rate (Lag)	-1.95 [1.94]	-0.60 [3.59]	0.20 [2.28]	6.16 [8.78]	-3.02 [2.41]	-2.75 [9.90]	-0.075 [4.66]	-2.28 [2.73]	10.3 [12.8]
Home: Urban population rate (Square, Lag)	0.016 [0.015]	-0.0026 [0.027]	0.0034 [0.019]	-0.030 [0.056]	0.023 [0.022]	0.017 [0.063]	-0.038 [0.045]	0.027 [0.024]	-0.061 [0.081]
Home: Energy use (Lag)	-0.00047 [0.0015]	0.0013 [0.0019]	-0.00065 [0.0022]	-0.00026 [0.0019]	0.0012 [0.0026]	-0.00075 [0.0025]	0.0031 [0.0057]	0.00011 [0.0027]	0.0023 [0.0023]
Contiguity	2.65* [1.47]	3.71* [2.09]	-0.34 [2.26]	4.70*** [1.71]	-3.29 [2.63]	2.88** [1.39]	-7.28** [3.37]	7.98 [6.28]	4.22 [4.30]
Common language	0.61 [1.03]	-2.29 [1.58]	4.04*** [1.61]	-0.71 [1.40]	4.67*** [1.61]	-1.70 [1.57]	2.03 [3.10]	6.82*** [2.14]	0.84 [2.10]
Colonial relationship	-4.12* [2.15]	-6.88* [3.99]	-3.18 [2.79]	-4.49** [1.97]	-13.3*** [4.09]	0.34 [1.38]	-6.01 [13.9]	-16.3*** [4.44]	-8.69** [4.08]
Common colonizer post 1945	1.45 [2.31]	2.96 [2.55]	7.70 [9.16]	-4.71 [4.90]	-1.26 [3.52]	-8.43 [5.52]	-1.76 [3.93]	15.7 [10.1]	-6.15 [5.29]
Currently in colonial relationship	-2.50 [8.62]		-6.29 [9.36]	3.88 [6.01]		10.8* [5.65]			
Colonial relationship post 1945	5.96* [3.55]	5.68 [5.04]	8.84 [5.95]	-1.18 [3.58]	10.1 [6.27]	-10.4** [4.41]	-1.06 [14.5]	11.6 [7.53]	4.72 [5.46]
Same country	-3.55 [2.19]	-0.16 [2.45]	-6.65 [4.21]	-1.51 [2.90]	-0.92 [3.81]	-1.92 [2.35]	7.27* [3.89]	0.91 [9.98]	-3.41 [5.68]
Landlocked (Home and Host)	372*** [42.3]	-28.8 [112.327]	70.8 [91.8]	-47.4 [60.0]	497 [187.261]	1,452*** [125]	512*** [35.0]	142 [98.2]	605*** [55.7]
Distance (Log)	0.95** [0.40]	0.62 [0.77]	1.66*** [0.63]	0.60 [0.51]	-0.92 [0.75]	-0.36 [0.57]	-0.15 [1.43]	-1.89* [1.01]	0.77 [1.00]
Constant	939*** [75.3]	1,611 [50.901]	1,766*** [284]	1,557*** [324]	-548	5,394*** [488]	427 [305]	-1,735*** [579]	1,023* [574]
Observations	68,838	30,349	38,489	36,702	32,136	14,289	7,936	24,200	22,413
R-squared	0.979	0.984	0.974	0.984	0.981	0.957	0.968	0.981	0.986
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Host FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Home FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-pair FE	No	No	No	No	No	No	No	No	No
RMSE	84.425	84.503	82.609	89.674	81.331	81.945	84.993	78.522	88.780

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 6.C6: Convergence to the partner average (with country pair & time fixed effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Heterogeneity							
	Full sample	Host country		Home country		Club convergence		Non-club Convergence	
VARIABLES	Convergence of host country to average of partner countries	Convergence of Southern host country to average of partner countries	Convergence of Northern host country to average of partner countries	Convergence of host country to average of Northern partner countries	Convergence of host country to average of Southern partner countries	Convergence of Northern host country to average of Northern partner countries	Convergence of Southern host country to average of Southern partner countries	Convergence of Northern host country to average of Northern partner countries	Convergence of Southern host country to average of Northern partner countries
FDI (Lag)	-0.000074 [0.00022]	0.0013 [0.0011]	-0.00011 [0.00021]	0.00013 [0.00023]	-0.0016 [0.0014]	-0.00011 [0.00022]	-0.0019 [0.0042]	-0.0015 [0.0014]	-0.00082 [0.0016]
Host: GDP per capita (Lag)	0.015*** [0.00082]	0.0031 [0.0031]	0.026*** [0.0012]	0.011*** [0.0012]	0.016*** [0.0012]	0.020*** [0.0019]	0.021*** [0.0068]	0.026*** [0.0016]	0.00058 [0.0036]
Host: GDP per capita (Square, Lag)	-1.3e-07*** [6.3e-09]	-3.9e-08 [3.4e-08]	-1.7e-07*** [6.8e-09]	-1.4e-07*** [1.0e-08]	-1.3e-07*** [7.7e-09]	-1.9e-07*** [1.1e-08]	-2.5e-07*** [7.4e-08]	-1.6e-07*** [7.8e-09]	-1.9e-08 [3.9e-08]
Host: Manufacturing (Lag)	-5.00*** [0.54]	-5.51*** [0.55]	-5.00 [3.44]	-6.56*** [0.69]	-6.77*** [1.24]	-63.5*** [5.37]	-4.17*** [1.52]	-23.3*** [4.39]	-4.58*** [0.68]
Host: Manufacturing (Square, Lag)	0.016*** [0.0028]	0.022*** [0.0030]	-0.062 [0.076]	0.020*** [0.0035]	0.048*** [0.012]	1.13*** [0.13]	0.032*** [0.011]	0.45*** [0.097]	0.015*** [0.0036]
Host: Urban population rate (Lag)	4.30*** [1.57]	-1.41 [2.24]	-39.4*** [7.30]	-6.16*** [2.71]	20.2*** [4.32]	-128*** [7.12]	4.48 [6.86]	72.9*** [12.9]	-17.4*** [3.64]
Host: Urban population rate (Square, Lag)	-0.061*** [0.011]	-0.033 [0.020]	0.23*** [0.044]	-0.017 [0.019]	-0.17*** [0.028]	0.74*** [0.041]	-0.087 [0.057]	-0.49*** [0.080]	0.086*** [0.029]
Host: Energy use (Lag)	0.0039*** [0.0011]	0.018*** [0.0031]	-0.00012 [0.0014]	0.0045*** [0.0016]	0.0060*** [0.0015]	0.0054*** [0.0015]	0.011* [0.0056]	0.010*** [0.0019]	0.016*** [0.0038]
Home: GDP per capita (Lag)	0.00084 [0.00099]	-0.000021 [0.0014]	0.0011 [0.0014]	-0.00012 [0.0015]	0.0066** [0.0027]	-6.0e-07 [0.0020]	0.012** [0.0049]	0.0035 [0.0030]	0.00035 [0.0019]
Home: GDP per capita (Square, Lag)	-6.4e-09 [7.8e-09]	-2.4e-09 [9.7e-09]	-1.4e-08 [1.2e-08]	-2.3e-10 [9.3e-09]	-6.9e-08** [3.2e-08]	-4.6e-10 [1.2e-08]	-1.2e-07** [5.9e-08]	-3.8e-08 [3.4e-08]	-2.6e-09 [1.2e-08]
Home: Manufacturing (Lag)	-0.046 [0.55]	0.039 [1.06]	0.15 [0.63]	0.95 [3.23]	-0.37 [0.64]	1.25 [3.98]	-1.42 [1.58]	-0.067 [0.68]	-2.69 [4.29]
Home: Manufacturing (Square, Lag)	0.00039 [0.0037]	-0.0023 [0.0064]	-0.00097 [0.0039]	-0.029 [0.084]	0.0026 [0.0041]	-0.029 [0.11]	0.0074 [0.0094]	0.00072 [0.0041]	0.047 [0.11]
Home: Urban population rate (Lag)	-1.81 [2.08]	-0.52 [3.75]	0.60 [2.45]	7.18 [9.07]	-3.49 [2.61]	-2.60 [9.98]	-0.62 [4.87]	-2.11 [2.97]	11.2 [13.2]
Home: Urban population rate (Square, Lag)	0.016 [0.016]	-0.0027 [0.028]	0.00052 [0.020]	-0.037 [0.058]	0.025 [0.023]	0.016 [0.064]	-0.039 [0.047]	0.025 [0.026]	-0.067 [0.084]
Home: Energy use (Lag)	-0.00066 [0.0015]	0.0012 [0.0019]	-0.00063 [0.0022]	-0.00074 [0.0020]	0.0017 [0.0027]	-0.00081 [0.0026]	0.0055 [0.0057]	-0.000048 [0.0028]	0.0020 [0.0024]
Constant	844*** [99.0]	1,240*** [155]	1,991*** [313]	1,072*** [378]	405** [183]	6,360*** [514]	737*** [244]	-1,835*** [521]	1,406*** [543]
Observations	68,838	30,349	38,489	36,702	32,136	14,289	7,936	24,200	22,413
R-squared	0.054	0.080	0.077	0.058	0.091	0.222	0.174	0.106	0.069
Number of id	7,221	3,234	3,987	3,537	3,684	1,193	890	2,794	2,344
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Host FE	No	No	No	No	No	No	No	No	No
Home FE	No	No	No	No	No	No	No	No	No
Country-pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RMSE	81.496	80.975	80.033	87.142	78.243	81.156	79.578	75.899	85.271

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 6.C7: Robustness with FDI (% Host Country GDP)

VARIABLES	(1)	(2)	(3)	(4)	(5)
FDI Net Inflow (% GDP, Lag)	-6.51*** [2.09]	-6.49*** [2.08]	-4.32*** [1.60]	-4.03** [1.82]	-0.11 [0.15]
Host: GDP per capita (Lag)	-0.0044*** [0.0015]	-0.0043*** [0.0015]	0.013*** [0.0028]	0.0083*** [0.0022]	0.0093*** [0.0013]
Host: GDP per capita (Square, Lag)	7.6e-08*** [1.6e-08]	7.5e-08*** [1.6e-08]	-7.7e-08*** [2.2e-08]	-6.6e-08*** [1.8e-08]	-1.2e-07*** [1.0e-08]
Host: Manufacturing (Lag)	-15.6*** [2.14]	-15.4*** [2.16]	-11.4*** [1.74]	-8.19*** [1.45]	-6.44*** [0.79]
Host: Manufacturing (Square, Lag)	0.15*** [0.020]	0.15*** [0.020]	0.073*** [0.014]	0.058*** [0.013]	0.025*** [0.0046]
Host: Urban population rate (Lag)	-2.72 [3.13]	-2.57 [3.13]	-25.5*** [6.90]	-12.6** [5.21]	-2.16 [2.98]
Host: Urban population rate (Square, Lag)	-0.032 [0.025]	-0.033 [0.025]	0.091* [0.052]	0.018 [0.039]	-0.018 [0.022]
Host: Energy use (Lag)	0.021*** [0.0053]	0.021*** [0.0053]	0.029*** [0.0053]	0.023*** [0.0048]	0.0097*** [0.0019]
Home: GDP per capita (Lag)	-0.0040*** [0.0015]	-0.0039*** [0.0015]	-0.0052*** [0.0013]	0.0020 [0.0022]	0.0078*** [0.0012]
Home: GDP per capita (Square, Lag)	8.7e-08*** [1.6e-08]	8.6e-08*** [1.6e-08]	9.6e-08*** [1.4e-08]	-3.4e-08* [1.8e-08]	-1.1e-07*** [1.0e-08]
Home: Manufacturing (Lag)	-13.4*** [2.19]	-13.3*** [2.21]	-13.8*** [2.02]	-7.55*** [1.53]	-7.08*** [0.80]
Home: Manufacturing (Square, Lag)	0.12*** [0.021]	0.12*** [0.021]	0.12*** [0.018]	0.038*** [0.013]	0.025*** [0.0047]
Home: Urban population rate (Lag)	1.25 [3.06]	1.36 [3.06]	1.95 [2.77]	-3.08 [5.00]	-0.093 [2.76]
Home: Urban population rate (Square, Lag)	-0.056** [0.024]	-0.057** [0.024]	-0.058*** [0.021]	-0.030 [0.037]	-0.027 [0.021]
Home: Energy use (Lag)	0.0090* [0.0052]	0.0089* [0.0052]	0.0051 [0.0045]	0.020*** [0.0049]	0.0092*** [0.0019]
Contiguity	-333*** [43.4]	-333*** [43.3]	-300*** [49.3]	-264*** [55.4]	
Common language	-173*** [30.8]	-173*** [30.8]	-129*** [30.1]	-45.1 [28.5]	
Colonial relationship	52.5 [74.5]	54.0 [74.5]	13.6 [72.6]	-40.0 [69.5]	
Common colonizer post 1945	48.1 [77.4]	48.5 [77.4]	-69.7 [85.0]	-224** [90.7]	
Currently in colonial relationship	-476 [311]	-479 [312]	-126 [265]	318 [219]	
Colonial relationship post 1945	410*** [114]	409*** [114]	306*** [106]	145 [96.8]	
Same country	-103 [71.2]	-103 [71.1]	66.3 [72.0]	230*** [70.3]	
Landlocked (Home and Host)	122*** [22.2]	122*** [22.3]	145*** [27.1]	94.9 [178]	
Distance (Log)	41.1*** [11.2]	40.7*** [11.2]	98.5*** [11.6]	157*** [12.2]	
Constant	1,611*** [184]	1,570*** [185]	2,022*** [319]	1,861*** [373]	1,492*** [154]
Observations	66,496	66,496	66,496	66,496	66,496
R-squared	0.093	0.094	0.324	0.579	0.047
Year FE	No	Yes	Yes	Yes	Yes
Host FE	No	No	Yes	Yes	No
Home FE	No	No	No	Yes	No
Country-pair FE	No	No	No	No	Yes
RMSE	788.558	788.502	681.669	538.262	113.562
Number of id					6,696

Robust standard errors in brackets

*** p<0.01, ** p<0.05, * p<0.1

General conclusion

In an increasingly interconnected world, where environmental challenges transcend borders, sustainable development-related issues have become unavoidable for all nations. This thesis explored the complex interactions between international economic dynamics and sustainability imperatives, particularly through the analysis of investment and its ambiguous role in sustainable development. By examining the differentiated effects of different forms of investment on environmental performance, as well as economic empowerment, access to energy, and individual well-being, this thesis sheds light on the strategies needed to reconcile economic development, environmental performance, and societal well-being

Specifically, this thesis examined the impact of Foreign Direct Investment (FDI) on environmental performance and convergence, women's empowerment in agriculture, the microeconomic effects of access to energy (notably electricity), the determinants and forecasts of economic optimism in sub-Saharan Africa, and the impact of macroeconomic shocks and FDI on industrial development.

Chapter 1 analyzed the effect of electrification on time allocation, intra-household inequalities, and labor market participation in Rwandan households. The findings show that access to electricity improves household welfare by increasing participation in the labor market, particularly for men. However, it also tends to widen income inequalities within households, especially by increasing the economic participation gap between men and women. This chapter highlights the importance of accompanying electrification policies with measures aimed at reducing gender inequalities.

Chapter 2 explored the impact of women's empowerment on food security in rural Ethiopian households. The study revealed that when women have better access to agricultural resources and actively participate in economic decision-making,

household food diversity significantly improves. Women's empowerment is also associated with increased caloric intake and reduced fears of food shortages. The chapter underscores that policies strengthening women's empowerment in agriculture are essential for combating malnutrition and ensuring food security in rural areas.

Chapter 3 uncovered a paradox in economic perceptions in sub-Saharan Africa. While the majority of citizens report having lived in challenging economic conditions, they remain optimistic about the future. This perception is largely influenced by institutional stability, social cohesion, and the quality of economic policies. The analysis shows that stable institutions and effective public policies are key drivers of economic optimism, even in contexts of present economic hardship.

Chapter 4 examined the effects of macroeconomic shocks on industrialization in emerging economies, particularly during periods of global uncertainty. The findings indicate that foreign direct investment (FDI) inflows play a positive and enduring role in industrialization, even in times of economic uncertainty. However, shocks related to international trade or GDP fluctuations have more variable and less predictable impacts. The chapter emphasizes that to ensure stable and sustainable industrialization, emerging economies should implement public policies that attract and stabilize FDI while protecting themselves from external economic shocks.

Chapter 5 demonstrated that the environmental effects of FDI flows and stocks are differentiated. FDI stocks are generally associated with improved environmental performance, particularly in emerging economies. In contrast, FDI flows, often tied to immediate economic gains, can result in negative environmental impacts, especially in regions like sub-Saharan Africa and the Middle East. The chapter concludes that public policies should focus on attracting large stocks of FDI while imposing stringent environmental regulations to minimize the negative effects of investments.

Chapter 6 shows that FDI flows between countries can either foster or hinder environmental convergence, depending on the nature of the trading partners. The results underline that FDI between developed countries (North-North) tends to promote positive convergence toward better environmental performance. In contrast, FDI flows between developed and developing countries (North-South) or between

developing countries (South-South) do not necessarily lead to improved environmental outcomes. This chapter highlights the need to regulate FDI with stricter environmental standards to ensure that foreign investments do not contribute to environmental degradation.

While each chapter addresses specific issues, they are all connected by a central question: how do foreign investments, access to energy, women's empowerment, and public policies influence sustainable and inclusive development?

The first two chapters explore microeconomic dynamics, in two African countries, focusing on access to electricity and women's empowerment in agriculture. These chapters highlight how economic policies and access to infrastructure directly impact household welfare, particularly for women. By emphasizing intra-household inequalities, they demonstrate that women's economic inclusion, along with access to resources such as electricity, plays a crucial role in reducing inequalities and improving overall well-being. Chapter 3 proposes both a micro and macro perspective as it examines economic perceptions at the individual level and shows how governance and macroeconomic stability shape future expectations in sub-Saharan Africa.

The subsequent chapters (4 to 6) broaden the analysis to a macroeconomic level, addressing larger development dynamics. They focus on the impact of FDI on industrialization and environmental sustainability, linking economic dynamics to sustainability imperatives. FDI, whether in the form of flows or stocks, plays a dual role: it promotes industrialization and economic performance in some regions but can also have negative environmental effects, especially in countries with weak regulations. The results indicate that while FDI can support economic dynamics, its environmental impact depends heavily on institutional frameworks and regulatory measures in place. A clear distinction is made between FDI stocks, which tend to be beneficial in the long run, and FDI flows, which are more volatile and often associated with negative environmental impacts.

These chapters use individual-level data to country-related information and demonstrate that sustainable development cannot be achieved without an integrated approach that combines improving living conditions, reducing inequalities, promoting industrialization, and preserving the environment. The connections between the chapters also underscore the importance of public policies and institutional frame-

work.

Public Policy Implications

The results of this thesis can be used to formulate recommendations for policymakers. The insights offered by this research suggest the formulation of public policies that not only optimize FDI, access to energy, and empowerment in both host and investing countries but also mitigate the potential adverse effects. These implications touch on several key areas: *economic and social policies*, *environmental policies*, and *institutional reforms*. Together, they aim ***to promote more inclusive, sustainable, and equitable development***.

For example, African rural electrification programs should include economic inclusion measures for women, such as subsidies for female entrepreneurs and professional training. Reforms to ensure women have access to productive assets are also necessary to ensure that everyone benefits from energy infrastructure. Land reforms might be necessary to guarantee equitable access to land and productive assets for women and disadvantaged households. This could include subsidy programs and microcredit systems to support investments in productive projects.

Further, our findings on the Sub-Saharan countries show that economic optimism in Africa is influenced by macroeconomic stability and trust in institutions. Governments should strengthen political and economic stability, improve governance, and invest in social infrastructure (education, healthcare) to sustain this optimism and encourage sustainable investments.

Moreover, we show that FDI flows can have varied environmental effects. It is essential to establish strict environmental regulations to ensure that FDI supports sustainable practices. Governments should also create incentives to attract FDI in green sectors (renewable energy, clean technologies). Investor countries should promote responsible practices by ensuring adherence to environmental standards and incorporating green technologies into their foreign investment projects. Moreover, regulations should discourage FDI in highly polluting industries (e.g., natural resource extraction, energy-intensive manufacturing) by imposing environmental compensation or carbon taxes.

Limitations and Research Perspectives

While this thesis contributes to the existing literature by analyzing in an original way different facets of international sustainable development, there are several limitations that should also be acknowledged. These also provide avenues for future research to further explore and refine the findings.

Our analyses face limitations in data quality and availability, particularly when it comes to survey data and developing countries' characteristics. This limits the sample sizes, which further restricts the use of specific econometric tools. Another limitation is related to the aggregate FDI data we use: we may overlook sector-specific impacts, while the lack of short- versus long-term analysis fails to capture temporal variations in FDI effects. Potential biases in countries that attract FDI, driven by factors like political stability, could also impact findings (i.e. there might be country characteristics that simultaneously influence countries' ability to attract FDI and their environmental performance). Additionally, our work does not fully account for the role of institutional frameworks and environmental regulations in shaping FDI's environmental outcomes, suggesting areas for future research to refine these influences.

To overcome these limitations, several future research avenues could be explored. An in-depth sectoral analysis can be performed: it would be useful to examine FDI impacts in specific sectors such as energy, agriculture, or heavy industry to better understand how these investments affect environmental performance in different industrial contexts. A more dynamic analysis distinguishing the immediate impacts of FDI from long-run consequences would allow for a better assessment of economic and environmental effects over time. Further, incorporating the institutional characteristics of countries into analysis models would provide a clearer understanding of how regulations influence FDI impacts. Further research could also focus on how institutional quality affects countries' ability to maximize FDI benefits while minimizing environmental costs.

One key finding of this thesis is the impact of infrastructure, such as access to electricity, on household welfare and gender inequality. However, future research could deepen the analysis of gender dynamics by exploring how other infrastructures (education, transport, healthcare) affect long-run economic and social outcomes,

particularly for women.

Future studies could assess the long-run effectiveness of women's empowerment policies (including energy access), tracking cohorts of women over several years to see how their access to resources and economic decision-making power evolve. Such research would help measure long-run benefits in terms of food security, family health, and the reduction of economic inequalities between men and women, as well as overall household welfare.

It would also be relevant to conduct comparative studies between different countries or regions to understand how gender-related development policies vary according to institutional contexts. For example, comparing the impact of women's empowerment policies in different African or Asian countries could reveal more effective and context-adapted approaches.

These future research directions will help to better understand how investment and development policies affect various dimensions of sustainable and inclusive development. By deepening sectoral analyses, gender dynamics, and regional specificities, our work can contribute to refining public policies and maximizing the economic, social, and environmental outcomes.

Bibliography

- Abay, K. A., Abdelfattah, L., El-Enbaby, H., Mahmoud, M. and Breisinger, C. (2022), ‘Plot size and sustainable input intensification in smallholder irrigated agriculture: Evidence from egypt’, *Agricultural Economics* **53**(5), 792–810. [126](#)
- Abegaz, G. A., Hassen, I. W. and Minten, B. (2018), *Consumption of animal-source foods in Ethiopia: Patterns, changes, and determinants*, Vol. 113, Intl Food Policy Res Inst. [127](#)
- Abrigo, M. R. and Love, I. (2016), ‘Estimation of panel vector autoregression in stata’, *The Stata Journal* **16**(3), 778–804. [199](#)
- Acharyya, J. (2009), ‘Fdi, growth and the environment: Evidence from india on co2 emission during the last two decades’, *Journal of economic development* **34**(1), 43. [4](#)
- Adeel-Farooq, R. M., Riaz, M. F. and Ali, T. (2021), ‘Improving the environment begins at home: Revisiting the links between fdi and environment’, *Energy* **215**, 119150. [230](#), [235](#), [238](#)
- AfDB (2024), ‘African Economic Outlook 2024 - Country Notes’.
URL: https://www.afdb.org/sites/default/files/2024/06/06/aeo2024_country_notes.pdf [120](#)
- African Development Bank Group (2015), *Les femmes dans l’agriculture en Afrique*, Technical report, African Development Bank Group. [120](#)
- African Development Bank Group (2024), ‘African Economic Outlook 2024 - Driving Africa’s Transformation: The Reform of the Global Financial Architecture’. Accessed: 2024-10-11.
URL: <https://www.afdb.org/en/knowledge/publications/african-economic-outlook> [143](#)

African Union Commission and OECD (2023), *Africa's Development Dynamics 2023: Investing in Sustainable Development*, OECD Publishing, Paris.

URL: <https://doi.org/10.1787/62d0ca31-en> 4

African Union Commission and OECD (2024), *Africa's Development Dynamics 2024: Skills, Jobs and Productivity*, OECD Publishing, Paris.

URL: <https://doi.org/10.1787/df06c7a4-en> 4

Aguilar, A., Carranza, E., Goldstein, M., Kilic, T. and Oseni, G. (2015), 'Decomposition of gender differentials in agricultural productivity in ethiopia', *Agricultural Economics* **46**(3), 311–334. 122

Ahmed, N., Marriott, A., Dabi, N., Lowthers, M., Lawson, M. and Mugehera, L. (2022), *Inequality kills: The unparalleled action needed to combat unprecedented inequality in the wake of COVID-19*, Oxfam. 1, 2

Ahouangbe, L. V. and Tritah, A. (2022), 'Access to electricity and children well-being: New evidence from rwanda 1', *Revue d'économie du développement* **31**(2), 43–49.

URL: <https://doi.org/10.3917/edd.362.0043>

Ahouangbe, V. L. and Turcu, C. (2024), 'How bilateral foreign direct investment influences environmental convergence', *The World Economy* **47**(1), 37–95.

URL: <https://doi.org/10.1111/twec.13532> 238, 241, 245

Alam, M. S., Miah, M. D., Hammoudeh, S. and Tiwari, A. K. (2018), 'The nexus between access to electricity and labour productivity in developing countries', *Energy policy* **122**, 715–726. Publisher: Elsevier. 18

Altshuler, C., Holland, D., Pingfan, H. and Li, H. (2016), 'The world economic forecasting model at the united nations', *Development* . 142

Andrews, D. W. and Lu, B. (2001), 'Consistent model and moment selection procedures for gmm estimation with application to dynamic panel data models', *Journal of Econometrics* **101**(1), 123–164. 198, 199

- Ansari, M. A. (2022), 'Re-visiting the environmental kuznets curve for asean: A comparison between ecological footprint and carbon dioxide emissions', *Renewable and Sustainable Energy Reviews* **168**, 112867. [238](#)
- Antràs, P. and Chor, D. (2022), 'Global value chains', *Handbook of international economics* **5**, 297–376. [1](#), [3](#)
- Apergis, N. (2016), 'Environmental kuznets curves: new evidence on both panel and country-level co2 emissions', *Energy Economics* **54**, 263–271. [197](#)
- Apergis, N., Christou, C. and Gupta, R. (2017), 'Are there environmental kuznets curves for us state-level co2 emissions?', *Renewable and Sustainable Energy Reviews* **69**, 551–558. [197](#)
- Apergis, N. and Payne, J. E. (2017), 'Per capita carbon dioxide emissions across us states by sector and fossil fuel source: evidence from club convergence tests', *Energy Economics* **63**, 365–372. [294](#)
- Appiah, M., Gyamfi, B. A., Adebayo, T. S. and Bekun, F. V. (2023), 'Do financial development, foreign direct investment, and economic growth enhance industrial development? fresh evidence from sub-sahara african countries', *Portuguese Economic Journal* **22**(2), 203–227. [197](#)
- Arellano, M. and Bover, O. (1995), 'Another look at the instrumental variable estimation of error-components models', *Journal of Econometrics* **68**(1), 29–51. [192](#)
- Asongu, S. A. and Odhiambo, N. M. (2020), 'Foreign direct investment, information technology and economic growth dynamics in sub-saharan africa', *Telecommunications Policy* **44**(1), 101838. [3](#)
- Atasoy, B. S. (2017), 'Testing the environmental kuznets curve hypothesis across the us: Evidence from panel mean group estimators', *Renewable and Sustainable Energy Reviews* **77**, 731–747. [197](#)
- Azzarri, C., Zezza, A., Haile, B. and Cross, E. (2015), 'Does livestock ownership affect animal source foods consumption and child nutritional status? evidence from rural uganda', *The Journal of Development Studies* **51**(8), 1034–1059. [121](#)

- Bai, J. and Perron, P. (1998), ‘Estimating and testing linear models with multiple structural changes’, *Econometrica* pp. 47–78. [206](#)
- Bai, J. and Perron, P. (2003), ‘Computation and analysis of multiple structural change models’, *Journal of Applied Econometrics* **18**(1), 1–22. [206](#)
- Balsalobre-Lorente, D., Gokmenoglu, K. K., Taspinar, N. and Cantos-Cantos, J. M. (2019), ‘An approach to the pollution haven and pollution halo hypotheses in mint countries’, *Environmental Science and Pollution Research* **26**(22), 23010–23026. [235](#)
- Balsalobre-Lorente, D., Ibáñez-Luzón, L., Usman, M. and Shahbaz, M. (2022), ‘The environmental kuznets curve, based on the economic complexity, and the pollution haven hypothesis in piigs countries’, *Renewable Energy* **185**, 1441–1455. [4](#)
- Barbosa, N. and Eiriz, V. (2009), ‘Linking corporate productivity to foreign direct investment: An empirical assessment’, *International Business Review* **18**(1), 1–13. [187](#)
- Barkat, A., Khan, S. H., Rahman, M., Zaman, S., Poddar, A., Halim, S., Ratna, N., Majid, M., Maksud, A. K. M. and Karim, A. (2002), ‘Economic and social impact evaluation study of the rural electrification program in Bangladesh’, *Report to National Rural Electric Cooperative Association (NRECA) International, Dhaka*. Publisher: Citeseer. [19](#), [21](#)
- Barrios, S., Görg, H. and Strobl, E. (2005), ‘Foreign direct investment, competition and industrial development in the host country’, *European Economic Review* **49**(7), 1761–1784. [187](#)
- Barron, M. and Torero, M. (2014), ‘Electrification and time allocation: experimental evidence from Northern El salvador’. [19](#), [21](#), [23](#), [44](#)
- Bashir, M. F. (2022), ‘Discovering the evolution of pollution haven hypothesis: A literature review and future research agenda’, *Environmental Science and Pollution Research* **29**(32), 48210–48232. [1](#), [230](#)
- Baumol, W. J. and Oates, W. E. (1988), *The theory of environmental policy*, Cambridge university press. [232](#), [247](#), [289](#)

- Becker, G. S. (1965), 'A Theory of the Allocation of Time', *The economic journal* **75**(299), 493–517. Publisher: JSTOR. [23](#)
- Belderbos, R. and Van Roy, V. (2011), Productivity spillovers from foreign affiliates and domestic firm internationalization: firm-level evidence for belgium, in 'Paper presented at the DIME Final Conference', Vol. 6, p. 8. [187](#)
- Bernard, J. and Mandal, S. (2016), 'The impact of trade openness on environmental quality: an empirical analysis of emerging and developing economies', *WIT Transactions on Ecology and the Environment* **203**, 195–208. [236](#)
- Bland, J. M. and Altman, D. G. (1997), 'Statistics notes: Cronbach's alpha', *Bmj* **314**(7080), 572. [152](#)
- Brandi, C., Schwab, J., Berger, A. and Morin, J.-F. (2020), 'Do environmental provisions in trade agreements make exports from developing countries greener?', *World Development* **129**, 104899. [232](#)
- Brännlund, R. and Karimu, A. (2018), 'Convergence in global environmental performance: assessing heterogeneity', *Environmental Economics and Policy Studies* **20**(3), 503–526. [293](#)
- Brännlund, R., Lundgren, T. and Söderholm, P. (2015), 'Convergence of carbon dioxide performance across swedish industrial sectors: an environmental index approach', *Energy Economics* **51**, 227–235. [293](#)
- Breiman, L., Friedman, J., Olshen, R. and Stone, C. (1984), 'Classification and regression trees. wadsworth int', *Group* **37**(15), 237–251. [158](#)
- Bressoux, P. (2007), 'L'apport des modèles multiniveaux à la recherche en éducation', *Éducation et didactique* **1**(2), 73–88. [148](#)
- Bridge, B. A., Adhikari, D. and Fontenla, M. (2016), 'Electricity, income, and quality of life', *The Social Science Journal* **53**(1), 33–39. Publisher: Elsevier. [18](#), [19](#), [22](#), [23](#), [31](#)
- Bu, M., Liu, Z., Wagner, M. and Yu, X. (2013), 'Corporate social responsibility and the pollution haven hypothesis: Evidence from multinationals' investment

- decision in china', *Asia-Pacific Journal of Accounting & Economics* **20**(1), 85–99. [235](#)
- Burnham, K. P. (2002), 'Information and likelihood theory: a basis for model selection and inference', *Model selection and multimodel inference: a practical information-theoretic approach* pp. 49–97. [155](#)
- Burnham, K. P. and Anderson, D. R. (2004), 'Multimodel inference: understanding aic and bic in model selection', *Sociological methods & research* **33**(2), 261–304. [155](#)
- Buxton, R. (2008), 'Multilevel modelling', *Mathematics Learning Support Centre* . [148](#)
- Buzasi, K. (2015), 'Languages, communication potential and generalized trust in sub-saharan africa: Evidence based on the afrobarometer survey', *Social science research* **49**, 141–155. [148](#), [149](#), [151](#)
- Cai, X., Lu, Y., Wu, M. and Yu, L. (2016), 'Does environmental regulation drive away inbound foreign direct investment? evidence from a quasi-natural experiment in china', *Journal of Development Economics* **123**, 73–85. [230](#), [233](#), [290](#)
- Camarero, M., Picazo-Tadeo, A. J. and Tamarit, C. (2008), 'Is the environmental performance of industrialized countries converging? a 'sure' approach to testing for convergence', *Ecological Economics* **66**(4), 653–661. [294](#)
- Camarero, M., Picazo-Tadeo, A. J. and Tamarit, C. (2013), 'Are the determinants of co2 emissions converging among oecd countries?', *Economics Letters* **118**(1), 159–162. [287](#), [294](#)
- Candau, F. and Dienesch, E. (2017), 'Pollution haven and corruption paradise', *Journal of Environmental Economics and Management* **85**, 171–192. [232](#), [289](#)
- Carabenciov, I., Freedman, M. C., Garcia-Saltos, M. R., Laxton, M. D., Kamenik, M. O. and Manchev, M. P. (2013), *GPM6: the global projection model with 6 regions*, number 13-87, International Monetary Fund. [142](#)

- Cariolle, J. (2018), ‘Insights from a multi-level analysis of corruption determinants in developing and transition countries’, *Available at SSRN 3135314* . [149](#)
- Chancel, L., Piketty, T., Saez, E. and Zucman, G. (2022), *World inequality report 2022*, Harvard University Press. [2](#)
- Cheong, T. S., Wu, Y., Wojewodzki, M. and Ma, N. (2021), ‘The impacts of globalization on inequality in the post-covid-19 world: evidence from china’, *Frontiers in Public Health* **9**, 790312. [4](#)
- Chepkirui, M. (2019), Influence Of Size And Crop Variety Of Kitchen Gardens On Dietary Diversity And Micronutrient Adequacy Among Women Of Reproductive Age In Kericho County, Kenya, PhD thesis, University of Nairobi. [121](#)
- Chichilnisky, G. (1994), ‘North-south trade and the global environment’, *The American Economic Review* pp. 851–874. [233](#)
- Chinn, M. D. and Ito, H. (2006), ‘What matters for financial development? capital controls, institutions, and interactions’, *Journal of Development Economics* **81**(1), 163–192. [185](#), [193](#)
- Chung, S. (2014), ‘Environmental regulation and foreign direct investment: Evidence from south korea’, *Journal of Development Economics* **108**, 222–236. [233](#), [290](#)
- Ciarli, T. and Di Maio, M. (2014), ‘2 theoretical arguments for industrialisation-driven economic growth and development1’, *African industrial development and European Union co-operation: prospects for a reengineered partnership* p. 30. [186](#)
- Clark, C. (1957), *The Conditions of economic progress*, number vol. 1, Mcmillan.
URL: <https://books.google.fr/books?id=hpKaAAAAIAAJ> [188](#), [189](#), [216](#)
- Cole, M. A., Elliott, R. J. and Fredriksson, P. G. (2006), ‘Endogenous pollution havens: Does fdi influence environmental regulations?’, *Scandinavian Journal of Economics* **108**(1), 157–178. [235](#), [237](#), [247](#), [289](#), [295](#)
- Cole, M. A., Elliott, R. J. and Strobl, E. (2008), ‘The environmental performance of firms: The role of foreign ownership, training, and experience’, *Ecological Economics* **65**(3), 538–546. [292](#)

- Cole, M. A., Elliott, R. J. and Zhang, L. (2017), 'Foreign direct investment and the environment', *Annual Review of Environment and Resources* **42**, 465–487. [234](#), [289](#), [291](#)
- Conley, T. G. (1999), 'GMM estimation with cross sectional dependence', *Journal of econometrics* **92**(1), 1–45. Publisher: Elsevier. [51](#)
- Costa, J., Hailu, D., Silva, E. and Tsukada, R. (2009), The implications of water and electricity supply for the time allocation of women in rural Ghana, Technical report, Working Paper. [21](#), [22](#)
- Crescenzi, R., Ganau, R. and Storper, M. (2022), 'Does foreign investment hurt job creation at home? the geography of outward fdi and employment in the usa', *Journal of economic geography* **22**(1), 53–79. [230](#)
- Cronbach, L. J. and Meehl, P. E. (1955), 'Construct validity in psychological tests.', *Psychological bulletin* **52**(4), 281. [152](#)
- Dam, L. and Scholtens, B. (2012), 'The curse of the haven: The impact of multinational enterprise on environmental regulation', *Ecological Economics* **78**, 148–156. [235](#)
- Dasgupta, U. and Mani, S. (2015), 'Only mine or all ours: Do stronger entitlements affect altruistic choices in the household', *World Development* **67**, 363–375. [121](#)
- Dasso, R. and Fernandez, F. (2015), 'The effects of electrification on employment in rural Peru', *IZA Journal of Labor & Development* **4**(1), 1–16. Publisher: Springer. [19](#), [22](#)
- De Ree, J. and Alessie, R. (2011), 'Life satisfaction and age: Dealing with underidentification in age-period-cohort models', *Social Science & Medicine* **73**(1), 177–182. [155](#)
- Dean, J. M., Lovely, M. E. and Wang, H. (2009), 'Are foreign investors attracted to weak environmental regulations? evaluating the evidence from china', *Journal of Development Economics* **90**(1), 1–13. [234](#), [290](#)

- Demena, B. A. and Afesorgbor, S. K. (2020), ‘The effect of fdi on environmental emissions: Evidence from a meta-analysis’, *Energy Policy* **138**, 111192. [230](#), [292](#), [293](#)
- Demir, F. (2016), ‘Effects of fdi flows on institutional development: does it matter where the investors are from?’, *World Development* **78**, 341–359. [295](#), [298](#), [300](#)
- Demir, F. and Duan, Y. (2018), ‘Bilateral fdi flows, productivity growth, and convergence: the north vs. the south’, *World Development* **101**, 235–249. [238](#), [295](#), [298](#)
- DeVellis, R. F. (2016), *Scale development: Theory and applications*, Vol. 26, Sage publications. [152](#)
- Dhrifi, A., Jaziri, R. and Alnahdi, S. (2020), ‘Does foreign direct investment and environmental degradation matter for poverty? evidence from developing countries’, *Structural Change and Economic Dynamics* **52**, 13–21. [1](#)
- Diez-Roux, A. V. (2000), ‘Multilevel analysis in public health research’, *Annual review of public health* **21**(1), 171–192. [148](#), [149](#)
- Dinkelman, T. (2011), ‘The effects of rural electrification on employment: New evidence from South Africa’, *American Economic Review* **101**(7), 3078–3108. [18](#), [19](#), [22](#), [23](#), [31](#), [44](#)
- Ditzen, J., Karavias, Y. and Westerlund, J. (2021), ‘Testing and estimating structural breaks in time series and panel data in stata’, *arXiv preprint arXiv:2110.14550* . [206](#)
- Dollar, D., Wolff, E. N., Wolff, E. N. et al. (1993), *Competitiveness, convergence, and international specialization*, Mit Press. [188](#), [190](#)
- Doss, C. R. and Quisumbing, A. R. (2020), ‘Understanding rural household behavior: Beyond booserup and becker’, *Agricultural Economics* **51**(1), 47–58. [121](#)
- Doytch, N. and Uctum, M. (2016), ‘Globalization and the environmental impact of sectoral fdi’, *Economic Systems* **40**(4), 582–594. [235](#), [247](#), [292](#)

- Druckenmiller, H. and Hsiang, S. (2018), Accounting for unobservable heterogeneity in cross section using spatial first differences, Technical report, National Bureau of Economic Research. [20](#), [34](#), [35](#), [36](#), [37](#), [40](#), [44](#), [71](#)
- Duan, Y. and Jiang, X. (2021), ‘Pollution haven or pollution halo? a re-evaluation on the role of multinational enterprises in global co2 emissions’, *Energy Economics* **97**, 105181. [235](#)
- Dulani, B., Mattes, R. and Logan, C. (2013), ‘After a decade of growth in africa, little change in poverty at the grassroots’, *Afrobarometer Policy Brief* **1**. [152](#)
- Emako, E., Nuru, S. and Menza, M. (2022), ‘The effect of foreign direct investment on economic growth in developing countries’, *Transnational Corporations Review* **14**(4), 382–401. [3](#)
- Eskeland, G. S. and Harrison, A. E. (2003), ‘Moving to greener pastures? multinationals and the pollution haven hypothesis’, *Journal of Development Economics* **70**(1), 1–23. [246](#), [292](#)
- Essandoh, O. K., Islam, M. and Kakinaka, M. (2020), ‘Linking international trade and foreign direct investment to co2 emissions: any differences between developed and developing countries?’, *Science of the Total Environment* **712**, 136437. [235](#)
- European Central Bank (2010), Monthly bulletin october 2010, Technical report, European Central Bank. [184](#)
- Fafchamps, M. and Quisumbing, A. R. (2002), ‘Control and ownership of assets within rural ethiopian households’, *Journal of development Studies* **38**(6), 47–82. [123](#)
- Fallahi, F. and Voia, M.-C. (2015), ‘Convergence and persistence in per capita energy use among oecd countries: Revisited using confidence intervals’, *Energy Economics* **52**, 246–253. [294](#)
- Fearon, J. D. and Laitin, D. D. (2003), ‘Ethnicity, insurgency, and civil war’, *American political science review* **97**(1), 75–90. [160](#)

Feenstra, R. C., Inklaar, R. and Timmer, M. P. (2015), 'The next generation of the penn world table', *American Economic Review* **105**(10), 3150–82.

URL: <http://www.aeaweb.org/articles?id=10.1257/aer.20130954> 185, 193

Food and Agriculture Organization and Organisation for Economic Co-operation and Development (2016), *Perspectives agricoles de l'OCDE et de la FAO 2016-2025*, Organisation for Economic Co-operation and Development (OECD), Paris. 120

Fredriksson, P. G., List, J. A. and Millimet, D. L. (2003), 'Bureaucratic corruption, environmental policy and inbound us fdi: theory and evidence', *Journal of Public Economics* **87**(7-8), 1407–1430. 289

Frijters, P. and Beatton, T. (2012), 'The mystery of the u-shaped relationship between happiness and age', *Journal of Economic Behavior & Organization* **82**(2-3), 525–542. 155

Frijters, P., Haisken-DeNew, J. P. and Shields, M. A. (2004), 'Investigating the patterns and determinants of life satisfaction in germany following reunification', *Journal of Human resources* **39**(3), 649–674. 155

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A. et al. (2015), 'The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes', *Scientific data* **2**(1), 1–21. 125

Gao, L. and Li, F. (2023), 'China's outward foreign direct investment and the environmental performance of the "belt and road initiative" countries', *Sustainability* **15**(15), 11899. 236

Gaymu, J. and Springer, S. (2010), 'Living conditions and life satisfaction of older europeans living alone: a gender and cross-country analysis', *Ageing & Society* **30**(7), 1153–1175. 151

Gereffi, G. (2019), 'Global value chains, development, and emerging economies', *Business and Development Studies. Routledge* pp. 125–158. 1, 3, 184

- Gereffi, G. and Sturgeon, T. (2013), ‘Global value chain-oriented industrial policy: the role of emerging economies’, *Global Value Chains in a Changing World* pp. 329–360. [3](#), [184](#)
- Givord, P., Guillerm, M. et al. (2016), Les modèles multiniveaux, Technical report, Institut National de la Statistique et des Etudes Economiques. [148](#), [158](#)
- Gong, M., You, Z., Wang, L. and Cheng, J. (2020), ‘Environmental regulation, trade comparative advantage, and the manufacturing industry’s green transformation and upgrading’, *International Journal of Environmental Research and Public Health* **17**(8), 2823. [232](#)
- Görg, H. and Greenaway, D. (2004), ‘Much ado about nothing? do domestic firms really benefit from foreign direct investment?’, *The World Bank Research Observer* **19**(2), 171–197. [187](#)
- Görg, H., Hijzen, A., Muraközy, B. et al. (2009), The role of production technology for productivity spillovers from multinationals: Firm-level evidence for hungary, Technical report, Kiel Working Paper. [188](#)
- Grogan, L. and Sadanand, A. (2013), ‘Rural electrification and employment in poor countries: Evidence from Nicaragua’, *World Development* **43**, 252–265. Publisher: Elsevier. [19](#), [21](#), [22](#), [23](#), [26](#), [31](#), [44](#)
- Gronau, R. (1977), ‘Leisure, home production, and work—the theory of the allocation of time revisited’, *Journal of political economy* **85**(6), 1099–1123. Publisher: The University of Chicago Press. [20](#), [23](#), [25](#), [70](#)
- Grossman, G. (1995), ‘Pollution and growth: What do we know?’, in “the economics of sustainable development”. edited by goldin i. and winters la’. [291](#)
- Grossman, G. M. and Krueger, A. B. (1991), ‘Environmental impacts of a north american free trade agreement’. [246](#), [290](#)
- Grossmann, A., Love, I. and Orlov, A. G. (2014), ‘The dynamics of exchange rate volatility: A panel var approach’, *Journal of International Financial Markets, Institutions and Money* **33**, 1–27. [203](#)

- Guerrieri, P. and Meliciani, V. (2005), ‘Technology and international competitiveness: The interdependence between manufacturing and producer services’, *Structural Change and Economic Dynamics* **16**(4), 489–502. [188](#), [190](#), [192](#)
- Gui-Diby, S. L. and Renard, M.-F. (2015), ‘Foreign direct investment inflows and the industrialization of african countries’, *World Development* **74**, 43–57. [187](#), [209](#)
- Hagemejer, J. and Kolasa, M. (2011), ‘Internationalisation and economic performance of enterprises: Evidence from polish firm-level data’, *The World Economy* **34**(1), 74–100. [187](#)
- Han, V., Ocal, O. and Aslan, A. (2023), ‘A revisit to the relationship between globalization and income inequality: are levels of development really paramount?’, *Quality & Quantity* **57**(1), 973–990. [4](#)
- Hanif, I., Raza, S. M. F., Gago-de Santos, P. and Abbas, Q. (2019), ‘Fossil fuels, foreign direct investment, and economic growth have triggered co2 emissions in emerging asian economies: some empirical evidence’, *Energy* **171**, 493–501. [230](#), [235](#), [247](#)
- Hanna, R. (2010), ‘Us environmental regulation and fdi: evidence from a panel of us-based multinational firms’, *American Economic Journal: Applied Economics* **2**(3), 158–89. [233](#), [290](#)
- Hansen, L. P. (1982), ‘Large sample properties of generalized method of moments estimators’, *Econometrica: Journal of the Econometric Society* pp. 1029–1054. [199](#)
- Haraguchi, N., Martorano, B. and Sanfilippo, M. (2018), ‘What factors drive successful industrialization? evidence and implications for developing countries’, *Structural Change and Economic Dynamics* . [186](#)
- Harrison, A. and Rodríguez-Clare, A. (2010), Trade, foreign investment, and industrial policy for developing countries, in ‘Handbook of Development Economics’, Vol. 5, Elsevier, pp. 4039–4214. [187](#), [188](#), [190](#)
- Hastie, T. (2009), ‘The elements of statistical learning: data mining, inference, and prediction’. [159](#)

- Hausman, J. A. (1978), 'Specification tests in econometrics', *Econometrica: Journal of the Econometric Society* pp. 1251–1271. [196](#)
- Herrerias, M. J. (2013), 'The environmental convergence hypothesis: carbon dioxide emissions according to the source of energy', *Energy Policy* **61**, 1140–1150. [287](#)
- Hoddinott, J., Headey, D. and Dereje, M. (2015), 'Cows, missing milk markets, and nutrition in rural ethiopia', *The Journal of Development Studies* **51**(8), 958–975. [127](#)
- Hollweg, C. H. (2019), 'Global value chains and employment in developing economies', *Global value chain development report 2019*, 63. [3](#)
- Hox, J. J. (1995), *Applied multilevel analysis*, TT-publikaties. [149](#)
- Hsiao, C. (1986), *Analysis of panel data*, number 11, Cambridge University press. [194](#)
- Hui, Y., Bhaumik, A. et al. (2023), 'Economic globalization and income inequality: A review', *Advancement in Management and Technology (AMT)* **3**(4), 1–9. [4](#)
- Hurlin, C. (2012), 'L'économétrie des données de panel: modèles linéaires simples', *École Doctorale Edocif*. [194](#)
- Hurlin, C. and Mignon, V. (2005), 'Une synthèse des tests de racine unitaire sur données de panel', *Economie Prevision* (3), 253–294. [196](#)
- Hutchison, M. L. (2011), 'Territorial threat and the decline of political trust in africa: A multilevel analysis', *Polity* **43**(4), 432–461. [151](#), [172](#), [173](#), [174](#), [175](#), [176](#), [177](#)
- Hutchison, M. L. and Johnson, K. (2011), 'Capacity to trust? institutional capacity, conflict, and political trust in africa, 2000–2005', *Journal of Peace Research* **48**(6), 737–752. [151](#), [172](#), [173](#), [174](#), [175](#), [176](#), [177](#)
- Hutchison, M. L. and Johnson, K. (2017), '27. political trust in sub-saharan africa and the arab region', *Handbook on political trust* p. 461. [151](#), [172](#), [173](#), [174](#), [175](#), [176](#), [177](#)

Huynh, C. M. and Hoang, H. H. (2019), ‘Foreign direct investment and air pollution in asian countries: does institutional quality matter?’, *Applied Economics Letters* **26**(17), 1388–1392. [235](#)

IEA, IRENA, U. W. W. (2020), *Tracking SDG 7: The Energy Progress Report*, World Bank, Washington, DC. © World Bank. License: Creative Commons Attribution—NonCommercial 3.0 IGO (CC BY-NC 3.0 IGO).

URL: <https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/May/SDG7Tracking>

Independent Evaluation Group (2008), The welfare impact of rural electrification: A reassessment of the costs and benefits, Technical report, Technical Report. [21](#)

International Energy Agency (2021), *Net zero by 2050: A roadmap for the global energy sector*, OECD Publishing. [2](#)

International Finance Corporation (2024), ‘IFC and zemen bank partner to strengthen trade finance in ethiopia’.

URL: <https://www.ifc.org/en/pressroom/2024/ifc-and-zemen-bank-partner-to-strengthen-trade-finance-in-ethiopia> [120](#)

International Food Policy Research Institute (2016), ‘Ethiopia Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) Baseline Evaluation Survey’.

URL: <https://doi.org/10.7910/DVN/H6RWO0> [123](#)

International Labour Organization (2020), Employment in africa: A focus on the agricultural sector, Technical report, ILO. [120](#)

International Monetary Fund (2022), *Global Financial Stability Report*, International Monetary Fund. [2](#)

International Monetary Fund. Research Dept. (2023), *World Economic Outlook Update, July 2023: Near-Term Resilience, Persistent Challenges*, International Monetary Fund, USA.

URL: <https://www.elibrary.imf.org/view/book/9798400243165/9798400243165.xml>
[142](#)

International Trade Administration (2024), ‘Ethiopia - agricultural sectors’.

URL: <https://www.trade.gov/country-commercial-guides/ethiopia-agricultural-sectors> 120

IPCC (2021), ‘Climate change 2021: the physical science basis’, *Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change*

IPCC Masson–Delmotte, Valérie and Zhai, Panmao and Pirani, Anna and Connors, Sarah and

2(1), 2391. 1, 2

Jakab, Z., Lukyantsau, P. and Wang, M. S. (2015), *A global projection model for Euro area large economies*, number 15-50, International Monetary Fund. 142

Javorcik, B. S. and Spatareanu, M. (2011), ‘Does it matter where you come from? vertical spillovers from foreign direct investment and the origin of investors’, *Journal of Development Economics* **96**(1), 126–138. 286, 287

Javorcik, B. S. and Wei, S.-J. (2003), ‘Pollution havens and foreign direct investment: dirty secret or popular myth?’, *Contributions in Economic Analysis & Policy* **3**(2). 234, 290

Joshanloo, M. (2018), ‘Gender differences in the predictors of life satisfaction across 150 nations’, *Personality and Individual Differences* **135**, 312–315. 151

Kalt, G., Wiedenhofer, D., Görg, C. and Haberl, H. (2019), ‘Conceptualizing energy services: A review of energy and well-being along the Energy Service Cascade’, *Energy Research & Social Science* **53**, 47–58. Publisher: Elsevier. 18

Kang, S. J. and Lee, H. (2011), ‘Foreign direct investment and de-industrialisation’, *The World Economy* **34**(2), 313–329. 184, 186, 188, 189, 190, 191, 192, 209

Kao, C. (1999), ‘Spurious regression and residual-based tests for cointegration in panel data’, *Journal of Econometrics* **90**(1), 1–44. 197

- Karalič, A. (1992), Employing linear regression in regression tree leaves, *in* 'Proceedings of the 10th European conference on Artificial intelligence', John Wiley & Sons, Inc., pp. 440–441. [158](#)
- Kaya, Y. (2010), 'Globalization and industrialization in 64 developing countries, 1980–2003', *Social Forces* **88**(3), 1153–1182. [187](#)
- Khan, I., Xue, J., Zaman, S. and Mehmood, Z. (2023), 'Nexus between fdi, economic growth, industrialization, and employment opportunities: empirical evidence from pakistan', *Journal of the Knowledge Economy* **14**(3), 3153–3175. [230](#)
- Khandker, S. R., Barnes, D. F. and Samad, H. A. (2013), 'Welfare impacts of rural electrification: A panel data analysis from Vietnam', *Economic Development and Cultural Change* **61**(3), 659–692. Publisher: University of Chicago Press Chicago, IL. [18](#), [19](#), [21](#), [22](#), [23](#), [31](#), [44](#)
- Kheder, S. B. and Zugravu, N. (2012), 'Environmental regulation and french firms location abroad: An economic geography model in an international comparative study', *Ecological Economics* **77**, 48–61. [233](#), [290](#)
- Kinati, W. and Mulema, A. A. (2018), 'Gender issues in livestock production in ethiopia: A review of literature to identify potential entry points for gender responsive research and development'. [125](#)
- Kirkpatrick, C. and Shimamoto, K. (2008), 'The effect of environmental regulation on the locational choice of japanese foreign direct investment', *Applied Economics* **40**(11), 1399–1409. [233](#)
- Kirkulak, B., Qiu, B. and Yin, W. (2011), 'The impact of fdi on air quality: evidence from china', *Journal of Chinese Economic and Foreign Trade Studies* . [230](#), [234](#), [246](#), [292](#)
- Kowalski, P., Gonzalez, J. L., Ragoussis, A. and Ugarte, C. (2015), 'Participation of developing countries in global value chains: Implications for trade and trade-related policies'. [3](#)

- Kozul-Wright, R. and Fortunato, P. (2019), 'Development unchained: Trade and industrialization in the era of international production', *Global Policy* **10**(1), 29–40. [188](#), [190](#)
- Krugman, P. R., Obstfeld, M. and Melitz, M. J. (2018), *International Economics, Theory and Policy, Global Edition*, 11 edn, Pearson Education Limited. [308](#)
- Kudina, A. and Pitelis, C. (2014), 'De-industrialisation, comparative economic performance and fdi inflows in emerging economies', *International Business Review* **23**(5), 887–896. [184](#)
- Kumar, N. (1995), 'Industrialisation, liberalisation and two way flows of foreign direct investments case of india', *Economic and Political Weekly* pp. 3228–3237. [189](#), [190](#)
- Lan, J., Kakinaka, M. and Huang, X. (2012), 'Foreign direct investment, human capital and environmental pollution in china', *Environmental and Resource Economics* **51**(2), 255–275. [235](#)
- Larson, J. B., Castellanos, P. and Jensen, L. (2019), 'Gender, household food security, and dietary diversity in western honduras', *Global food security* **20**, 170–179. [130](#)
- Lau, L.-S., Choong, C.-K. and Eng, Y.-K. (2014), 'Investigation of the environmental kuznets curve for carbon emissions in malaysia: do foreign direct investment and trade matter?', *Energy Policy* **68**, 490–497. [235](#), [292](#)
- Lau, L.-S., Ng, C.-F., Cheah, S.-P. and Choong, C.-K. (2019), Panel data analysis (stationarity, cointegration, and causality), in 'Environmental Kuznets Curve (EKC)', Elsevier, pp. 101–113. [196](#), [197](#)
- Lavallée, E., Razafindrakoto, M. and Roubaud, F. (2008), Corruption and trust in political institutions in sub-saharan africa, in 'CSAE Conference 2008-Economic Development in Africa', p. 21. [149](#)
- Leal, P. H. and Marques, A. C. (2022), 'The evolution of the environmental kuznets curve hypothesis assessment: A literature review under a critical analysis perspective', *Heliyon* **8**(11). [238](#)

- Lever, J., Krzywinski, M. and Altman, N. (2017), 'Points of significance: Principal component analysis', *Nature methods* **14**(7), 641–643. [125](#)
- Li, Z., Dong, H., Huang, Z. and Failler, P. (2019), 'Impact of foreign direct investment on environmental performance', *Sustainability* **11**(13), 3538. [236](#)
- Liu, Z. (2002), 'Foreign direct investment and technology spillover: Evidence from china', *Journal of Comparative Economics* **30**(3), 579–602. [187](#)
- Lo, S. B. and Ramde, F. (2019), 'Développement financier et transformation structurelle des pays africains de la zone franc: une approche panel-var', *Revue Interventions Economiques. Papers in Political Economy* (61). [197](#)
- Loh, W.-Y. (2011), 'Classification and regression trees', *Wiley interdisciplinary reviews: data mining and knowledge discovery* **1**(1), 14–23. [159](#)
- Love, I. and Zicchino, L. (2006), 'Financial development and dynamic investment behavior: Evidence from panel var', *The Quarterly Review of Economics and Finance* **46**(2), 190–210. [192](#), [194](#)
- Maddala, G. S. and Wu, S. (1999), 'A comparative study of unit root tests with panel data and a new simple test', *Oxford Bulletin of Economics and Statistics* **61**(S1), 631–652. [196](#)
- Mahbub, T., Ahammad, M. F., Tarba, S. Y. and Mallick, S. Y. (2022), 'Factors encouraging foreign direct investment (fdi) in the wind and solar energy sector in an emerging country', *Energy Strategy Reviews* **41**, 100865. [3](#)
- Mahmood, H., Furqan, M., Hassan, M. S. and Rej, S. (2023), 'The environmental kuznets curve (ekc) hypothesis in china: A review', *Sustainability* **15**(7), 6110. [238](#)
- Mahmud, S., Shah, N. M. and Becker, S. (2012), 'Measurement of women's empowerment in rural bangladesh', *World development* **40**(3), 610–619. [122](#)
- Malapit, H. J., Kadiyala, S., Quisumbing, A. R., Cunningham, K. and Tyagi, P. (2013), 'Women's empowerment in agriculture, production diversity, and nutrition: Evidence from nepal'. [121](#)

- Malapit, H. J. L., Sraboni, E., Quisumbing, A. R. and Ahmed, A. U. (2019), 'Intrahousehold empowerment gaps in agriculture and children's well-being in bangladesh', *Development Policy Review* **37**(2), 176–203. [121](#)
- Mallick, H., Mahalik, M. K. and Padhan, H. (2020), 'Does globalization exacerbate income inequality in two largest emerging economies? the role of fdi and remittances inflows', *International Review of Economics* **67**(4), 443–480. [4](#)
- Manderson, E. and Kneller, R. (2012), 'Environmental regulations, outward fdi and heterogeneous firms: are countries used as pollution havens?', *Environmental and Resource Economics* **51**(3), 317–352. [234](#), [235](#), [290](#)
- Mariana, V. D. (2011), 'Foreign direct investments during financial crises', *Annals of the University of Oradea, Economic Science Series* **20**(2), 41–45. [184](#)
- Markusen, J. R., Morey, E. R. and Olewiler, N. (1992), 'Noncooperative equilibria in regional environmental policies when plant locations are endogenous'. [232](#), [289](#)
- Markusen, J. R., Morey, E. R. and Olewiler, N. (1995), 'Competition in regional environmental policies when plant locations are endogenous', *Journal of Public Economics* **56**(1), 55–77. [232](#), [289](#)
- Markusen, J. R., Morey, E. R. and Olewiler, N. D. (1993), 'Environmental policy when market structure and plant locations are endogenous', *Journal of Environmental Economics and Management* **24**(1), 69–86. [232](#), [289](#)
- Markusen, J. R. and Venables, A. J. (1999), 'Foreign direct investment as a catalyst for industrial development', *European Economic Review* **43**(2), 335–356. [184](#), [186](#)
- Mattes, R. (2008), The material and political bases of lived poverty in africa: Insights from the afrobarometer, in 'Barometers of quality of life around the globe', Springer, pp. 161–185. [152](#)
- Mattes, R., Dulani, B. and Gyimah-Boadi, E. (2016), 'Africa's growth dividend? lived poverty drops across much of the continent'. [152](#)
- McAusland, C. (2010), 'Globalisation's direct and indirect effects on the environment'. [232](#)

- Mensah, J. T. and Traore, N. (2024), 'Infrastructure quality and fdi inflows: Evidence from the arrival of high-speed internet in africa', *The World Bank Economic Review* **38**(1), 1–23. [230](#)
- Merlevede, B., Schoors, K. and Spatareanu, M. (2014), 'Fdi spillovers and time since foreign entry', *World Development* **56**, 108–126. [187](#)
- Millimet, D. L. and Roy, J. (2016), 'Empirical tests of the pollution haven hypothesis when environmental regulation is endogenous', *Journal of Applied Econometrics* **31**(4), 652–677. [289](#)
- Mohammed, N. (2019), 'Industrialisation and economic development', *International Journal of Humanities and Social Science Research* **5**(5), 26–27. [186](#)
- Moore, E., Brandl, K., Doh, J. and Meyer, C. (2024), 'Natural-resources-seeking fdi and employment opportunities in developing countries: a temporal perspective', *International Journal of Development Issues* **23**(2), 304–324. [230](#)
- Mosley, L. and Rosendorff, B. P. (2023), 'Government choices of debt instruments', *International Studies Quarterly* **67**(2), sqad030. [152](#)
- Motta, M. and Thisse, J.-F. (1994), 'Does environmental dumping lead to delocation?', *European Economic Review* **38**(3-4), 563–576. [232](#), [289](#)
- Mulema, A. A., Farnworth, C. R. and Colverson, K. E. (2017), 'Gender-based constraints and opportunities to women's participation in the small ruminant value chain in ethiopia: A community capitals analysis', *Community Development* **48**(3), 351–369. [123](#)
- Mulugeta, M. and Amsalu, T. (2014), 'Gender, participation and decision making process in farming activities: The case of yilman densa district, amhara region, ethiopia', *Journal of Economics and Sustainable Development* **5**(1), 28–34. [122](#), [123](#)
- Murthy, S. K. (1998), 'Automatic construction of decision trees from data: A multi-disciplinary survey', *Data mining and knowledge discovery* **2**(4), 345–389. [158](#)

- Nasir, M. A., Huynh, T. L. D. and Tram, H. T. X. (2019), ‘Role of financial development, economic growth & foreign direct investment in driving climate change: A case of emerging asean’, *Journal of Environmental Management* **242**, 131–141. [233](#), [290](#)
- Naughton, B. (2012), *The China circle: Economics and technology in the PRC, Taiwan, and Hong Kong*, Brookings Institution Press. [184](#)
- Nicolini, M. and Resmini, L. (2010), ‘Fdi spillovers in new eu member states’, *Economics of Transition* **18**(3), 487–511. [187](#)
- NISR, N. I. o. S. o. R. (2018a), ‘Labour force survey trends, august 2018 report, december 2018’. [34](#)
- NISR, N. I. o. S. o. R. (2018b), ‘Labour force survey trends, february 2018 report, june 2018’. [34](#)
- NISR, N. I. o. S. o. R. (2020), ‘Labour force survey, annual report 2019, march 2020’. [33](#)
- Noble, M. and Wright, G. (2013), ‘Using indicators of multiple deprivation to demonstrate the spatial legacy of apartheid in south africa’, *Social Indicators Research* **112**(1), 187–201. [152](#)
- OECD (2022), *OECD Economic Outlook, Volume 2022 Issue 1*, OECD Publishing, Paris.
URL: <https://www.oecd-ilibrary.org/content/publication/62d0ca31-en> [2](#), [3](#)
- OECD (2023), *OECD Economic Outlook, Interim Report March 2023*, OECD Publishing, Paris.
URL: <https://www.oecd-ilibrary.org/content/publication/d14d49eb-en> [2](#)
- OECD (2024), *OECD Economic Outlook, Interim Report September 2024*, OECD Economic Policy Papers.
URL: <https://www.oecd-ilibrary.org/content/publication/1517c196-en> [142](#)
- OECD, S. (1997), ‘Negotiating group on the multilateral agreement on investment, prepared during mai negotiations.(1995-1998)“foreign direct investment and the environment: An overview of the literature”’, *DAFFE/MAI* **97**(33), 1. [289](#)

- of Rural Reconstruction, I. I. (2003), *Culture and Change: Ethiopian Women Challenging the Future*, iirr, ed edn, International Institute of Rural Reconstruction. [122](#)
- Ogola, P. F. A., Davidsdottir, B. and Fridleifsson, I. B. (2011), 'Lighting villages at the end of the line with geothermal energy in eastern Baringo lowlands, Kenya—Steps towards reaching the Millennium Development Goals (MDGs)', *Renewable and Sustainable Energy Reviews* **15**(8), 4067–4079. Publisher: Elsevier. [18](#)
- Organisation for Economic Co-operation and Development (2009), *Globalisation and emerging economies: Brazil, Russia, India, Indonesia, China and South Africa*, Organisation for Economic Co-operation and Development. [217](#)
- Osborne, J. (2000), 'Advantages of hierarchical linear modeling. pract assess res eval. 2000; 7 (1)'. [148](#), [149](#)
- Oshio, T. (2012), 'Gender differences in the associations of life satisfaction with family and social relations among the japanese elderly', *Journal of Cross-Cultural Gerontology* **27**(3), 259–274. [151](#)
- Osode, O. E., Iheonu, C. O. and Dauda, R. (2022), 'On the relationship between globalization and income inequality: Does institution matter?', *Journal of Public Affairs* **22**(2), e2433. [4](#)
- Pagliari, M. S. and Hannan, S. A. (2017), *The volatility of capital flows in emerging markets: Measures and determinants*, International Monetary Fund. [184](#)
- Partridge, M. and Jabri, M. (2000), Robust principal component analysis, in 'Neural Networks for Signal Processing X. Proceedings of the 2000 IEEE Signal Processing Society Workshop (Cat. No. 00TH8501)', Vol. 1, IEEE, pp. 289–298. [125](#)
- Paul, A. G. J. (2000), *Cluster analysis.*, Academic Press, pp. 297–321. [125](#)
- Pazienza, P. (2019), 'The impact of fdi in the oecd manufacturing sector on co2 emission: Evidence and policy issues', *Environmental Impact Assessment Review* **77**, 60–68. [230](#), [234](#), [292](#)

- Pelz, S. and Urpelainen, J. (2020), ‘Measuring and explaining household access to electrical energy services: Evidence from rural northern India’, *Energy Policy* **145**, 111782. Publisher: Elsevier. [18](#)
- Pesaran, M. H. (2004), ‘General diagnostic tests for cross section dependence in panels’, *Available at SSRN 572504* . [196](#)
- Pesaran, M. H. (2007), ‘A simple panel unit root test in the presence of cross-section dependence’, *Journal of Applied Econometrics* **22**(2), 265–312. [197](#)
- Pesaran, M. H. (2015), ‘Testing weak cross-sectional dependence in large panels’, *Econometric Reviews* **34**(6-10), 1089–1117. [196](#)
- Pesaran, M. H. (2021), ‘General diagnostic tests for cross-sectional dependence in panels’, *Empirical Economics* **60**(1), 13–50. [196](#)
- Peterson, R. A. (1995), ‘Une méta-analyse du coefficient alpha de cronbach’, *Recherche et Applications en Marketing (French Edition)* **10**(2), 75–88. [152](#)
- Posner, D. N. (2004), ‘Measuring ethnic fractionalization in africa’, *American journal of political science* **48**(4), 849–863. [160](#)
- Potters, J. and Sloof, R. (1996), ‘Interest groups: A survey of empirical models that try to assess their influence’, *European Journal of Political Economy* **12**(3), 403–442. [238](#), [296](#)
- Pueyo, A. and Maestre, M. (2019), ‘Linking energy access, gender and poverty: A review of the literature on productive uses of energy’, *Energy Research & Social Science* **53**, 170–181. Publisher: Elsevier. [18](#), [19](#), [22](#)
- Quisumbing, A., Meinzen-Dick, R. S. and Njuki, J. (2019), *2019 Annual trends and outlook report: Gender equality in rural Africa: From commitments to outcomes*, Intl Food Policy Res Inst. [121](#)
- Raihan, A. (2023), ‘Exploring environmental kuznets curve and pollution haven hypothesis in bangladesh: the impact of foreign direct investment’, *Journal of Environmental Science and Economics* **2**(1), 25–36. [4](#)

- Ramde, F. (2017), Institution, investissements et croissance dans l'uemoa: une approche panel var [institution, investments and growth in waemu: a panel var approach], Technical report, University Library of Munich, Germany. [194](#)
- Raspiller, S. and Riedinger, N. (2008), 'Do environmental regulations influence the location behavior of french firms?', *Land Economics* **84**(3), 382–395. [234](#), [290](#)
- Rathi, S. S. and Vermaak, C. (2018), 'Rural electrification, gender and the labor market: A cross-country study of India and South Africa', *World Development* **109**, 346–359. Publisher: Elsevier. [19](#), [23](#)
- Rezza, A. A. (2015), 'A meta-analysis of fdi and environmental regulations', *Environment and Development Economics* **20**(2), 185–208. [289](#), [293](#)
- Robinson, P. M. (1988), 'Root-n-consistent semiparametric regression', *Econometrica: Journal of the Econometric Society* pp. 931–954. [35](#), [44](#)
- Rodriguez-Clare, A. (1996), 'Multinationals, linkages, and economic development', *The American Economic Review* pp. 852–873. [184](#), [186](#)
- Rokach, L. (2010), *Pattern classification using ensemble methods*, Vol. 75, World Scientific. [158](#)
- Rokach, L. and Maimon, O. (2005), Decision trees, in 'Data mining and knowledge discovery handbook', Springer, pp. 165–192. [158](#), [159](#)
- Rokach, L. and Maimon, O. Z. (2008), *Data mining with decision trees: theory and applications*, Vol. 69, World scientific. [158](#)
- Rosenbaum, D. P. and Hanson, G. S. (1998), 'Assessing the effects of school-based drug education: A six-year multilevel analysis of project dare', *Journal of research in crime and delinquency* **35**(4), 381–412. [149](#)
- Ross, A. (2006), *Fast boat to China: Corporate flight and the consequences of free trade; Lessons from Shanghai*, Vintage. [184](#)
- Rutstein, S. O. and Johnson, K. (2004), 'The dhs wealth index. dhs comparative reports no. 6', *Calverton: ORC Macro* . [44](#)

- Röllin, H. B., Mathee, A., Bruce, N., Levin, J. and von Schirnding, Y. E. (2004), 'Comparison of indoor air quality in electrified and un-electrified dwellings in rural South African villages.', *Indoor Air* **14**(3), 208–216. [21](#)
- Sachs, J. D., Shatz, H. J., Deardorff, A. and Hall, R. E. (1994), 'Trade and jobs in us manufacturing', *Brookings Papers on Economic Activity* **1994**(1), 1–84. [188](#), [189](#), [190](#)
- Salmon, C. and Tanguy, J. (2016), 'Rural electrification and household labor supply: Evidence from Nigeria', *World development* **82**, 48–68. Publisher: Elsevier. [21](#), [22](#), [23](#), [31](#), [44](#)
- Samouel, B. and Aram, B. (2016), 'The determinants of industrialization: Empirical evidence for africa', *European Scientific Journal* **12**(10), 219–239. [209](#), [215](#)
- Saqib, N., Ozturk, I., Usman, M., Sharif, A. and Razzaq, A. (2023), 'Pollution haven or halo? how european countries leverage fdi, energy, and human capital to alleviate their ecological footprint', *Gondwana Research* **116**, 136–148. [3](#)
- Sarkodie, S. A. and Strezov, V. (2019), 'Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries', *Science of the Total Environment* **646**, 862–871. [4](#), [230](#), [233](#), [248](#), [290](#)
- Saucedo, E., Ozuna Jr, T. and Zamora, H. (2020), 'The effect of fdi on low and high-skilled employment and wages in mexico: a study for the manufacture and service sectors', *Journal for labour market research* **54**(1), 9. [3](#)
- Seyoum, B. (2024), Industrialization and the role of foreign direct investment, in 'State Fragility, Business, and Economic Performance: An Ethiopian Perspective', Springer, pp. 179–224. [1](#)
- Shahbaz, M., Balsalobre-Lorente, D. and Sinha, A. (2019), 'Foreign direct investment–co2 emissions nexus in middle east and north african countries: Importance of biomass energy consumption', *Journal of Cleaner Production* **217**, 603–614. [233](#), [290](#)

Shao, Q., Wang, X., Zhou, Q. and Balogh, L. (2019), ‘Pollution haven hypothesis revisited: a comparison of the brics and mint countries based on vecm approach’, *Journal of Cleaner Production* **227**, 724–738. [233](#), [290](#)

Sheahan, M. and Barrett, C. B. (2017), ‘Ten striking facts about agricultural input use in sub-saharan africa’, *Food policy* **67**, 12–25. [126](#)

Shucksmith, M., Cameron, S., Merridew, T. and Pichler, F. (2009), ‘Urban–rural differences in quality of life across the european union’, *Regional Studies* **43**(10), 1275–1289. [151](#)

Shyu, C.-W. (2014), ‘Ensuring access to electricity and minimum basic electricity needs as a goal for the post-MDG development agenda after 2015’, *Energy for Sustainable Development* **19**, 29–38. Publisher: Elsevier. [18](#)

Singhania, M. and Saini, N. (2021), ‘Demystifying pollution haven hypothesis: Role of fdi’, *Journal of Business Research* **123**, 516–528. [235](#)

Smarzynska Javorcik, B. (2004), ‘Does foreign direct investment increase the productivity of domestic firms? in search of spillovers through backward linkages’, *American Economic Review* **94**(3), 605–627. [287](#)

Sørensen, J. F. (2014), ‘Rural–urban differences in life satisfaction: Evidence from the european union’, *Regional Studies* **48**(9), 1451–1466. [151](#)

Sraboni, E., Malapit, H. J., Quisumbing, A. R. and Ahmed, A. U. (2014), ‘Women’s empowerment in agriculture: What role for food security in bangladesh?’, *World development* **61**, 11–52. [130](#)

Steenbergen, V., Liu, Y.-., Pinzon Latorre, M. A. and Zhu., X. (2022), ‘The world bank’s harmonized bilateral fdi databases : Methodology, trends, and possible use cases (English).’.

URL: <http://documents.worldbank.org/curated/en/099800006252213235/P17549906a3e950d0bf140>
[239](#)

Subramanian, S., Jones, K. and Duncan, C. (2003), *Multilevel methods for public health research*, Neighborhoods and health. New York: Oxford University Press.
[149](#)

- Talukder, A., Kiess, L., Huq, N., De Pee, S., Darnton-Hill, I. and Bloem, M. W. (2000), 'Increasing the production and consumption of vitamin a-rich fruits and vegetables: lessons learned in taking the bangladesh homestead gardening programme to a national scale', *Food and nutrition bulletin* **21**(2), 165–172. [121](#)
- Tang, J. (2015), 'Testing the pollution haven effect: Does the type of fdi matter?', *Environmental and Resource Economics* **60**(4), 549–578. [232](#), [289](#)
- Teklu, A. (2005), *Research report 4 land registration and women's land rights in Amhara region, Ethiopia*, International Institute for Environment and Development. [122](#)
- Tienhaara, K. (2010), 'A tale of two crises: What the global financial crisis means for the global environmental crisis', *Environmental Policy and Governance* **20**(3), 197–208. [300](#)
- Tiruneh, Y. S., Hughes, N. R. and Kandula, K. (2023), 'Supporting ethiopian women farmers in adapting to a changing climate', <https://blogs.worldbank.org/en/nasikiliza/supporting-ethiopian-women-farmers-adapting-changing-climate>. Accessed: 2024-10-11. [122](#)
- Tole, L. and Koop, G. (2011), 'Do environmental regulations affect the location decisions of multinational gold mining firms?', *Journal of Economic Geography* **11**(1), 151–177. [233](#), [290](#)
- Tom, A., Bosker, T. A. S. R. J. and Bosker, R. J. (1999), *Multilevel analysis: an introduction to basic and advanced multilevel modeling*, Sage. [149](#)
- Torkelsson, Å. and Tassew, B. (2008), 'Quantifying women's and men's rural resource portfolios—empirical evidence from western shoa in ethiopia', *The European Journal of Development Research* **20**, 462–481. [122](#)
- Tovar, C. E. (2009), 'Dsge models and central banks', *Economics: The Open-Access, Open-Assessment E-Journal* **3**. [142](#)
- Tsegaye, D., Dessalegn, T., Yimam, A. and Kefale, M. (2012), 'Extent of rural women participation and decision making in seed production activities', *Global Advanced Research Journal of Agricultural Science* **1**(7), 186–190. [122](#)

- Tsoy, L. and Heshmati, A. (2023), ‘Is fdi inflow bad for environmental sustainability?’, *Environment, Development and Sustainability* pp. 1–16. [236](#)
- Turner, D. (2016), ‘The use of models in producing oecd macroeconomic forecasts’. [142](#)
- Ulucak, R. and Apergis, N. (2018), ‘Does convergence really matter for the environment? an application based on club convergence and on the ecological footprint concept for the eu countries’, *Environmental Science & Policy* **80**, 21–27. [294](#)
- UN. Department of Economic and Social Affairs (2022), *The sustainable development goals report 2022*, United Nations. [3](#)
- UNCTAD (2021), *World investment report 2021: Investing in sustainable recovery*, United Nations. [1](#), [2](#)
- United Nations (2014), ‘L’agriculture, une affaire de femmes’. Publisher: United Nations. [120](#)
- United Nations (2015), ‘Transforming our world: The 2030 agenda for sustainable development’, *New York: United Nations, Department of Economic and Social Affairs* **1**, 41. [2](#)
- United Nations (2018), ‘East-African Countries Lead in the localization of the SDGs relating to Women’s Land Rights’.
- URL:** <https://africa.unwomen.org/en/news-and-events/stories/2018/02/east-africa-leading-the-way-in-women-land-rights> [121](#)
- United Nations Conference on Trade and Development (2019), *World investment report 2019: Special economic zones*, UN. [184](#)
- United Nations Department of Economic and Social Affairs (2024), ‘World Economic Situation and Prospects 2024’. Accessed: 2024-10-11.
- URL:** <https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/WESP2024Web.pdf> [142](#)
- USAID (2018), ‘Gender equality and women’s empowerment | ethiopia | archive - u.s. agency for international development’.

URL: <https://2017-2020.usaid.gov/ethiopia/gender-equality-and-womens-empowerment> 120

USAID (2021), ‘Agriculture and food security | ethiopia | archive - u.s. agency for international development’.

URL: <https://2017-2020.usaid.gov/ethiopia/agriculture-and-food-security> 120

USAID (2023), ‘Empowering women through agricultural development in ethiopia | archive - u.s. agency for international development’.

URL: <https://2012-2017.usaid.gov/results-data/success-stories/empowering-women-through-agricultural-development-ethiopia> 120, 122

Van de Walle, D., Ravallion, M., Mendiratta, V. and Koolwal, G. (2013), *Long-term impacts of household electrification in rural India*, The World Bank. 19, 23, 44

Vanderlinde, R., Aesaert, K. and Van Braak, J. (2014), ‘Institutionalised ict use in primary education: A multilevel analysis’, *Computers & Education* **72**, 1–10. 149

Wagner, U. J. and Timmins, C. D. (2009), ‘Agglomeration effects in foreign direct investment and the pollution haven hypothesis’, *Environmental and Resource Economics* **43**(2), 231–256. 233, 248, 290

Waldkirch, A. and Ofosu, A. (2010), ‘Foreign presence, spillovers, and productivity: Evidence from ghana’, *World Development* **38**(8), 1114–1126. 188

Wang, H. and Liu, H. (2019), ‘Foreign direct investment, environmental regulation, and environmental pollution: an empirical study based on threshold effects for different chinese regions’, *Environmental Science and Pollution Research* **26**(6), 5394–5409. 230, 235, 292

Wang, X., Zhang, C. and Zhang, Z. (2019), ‘Pollution haven or porter? the impact of environmental regulation on location choices of pollution-intensive firms in china’, *Journal of Environmental Management* **248**, 109248. 233, 290

Westerlund, J. (2007), ‘Testing for error correction in panel data’, *Oxford Bulletin of Economics and Statistics* **69**(6), 709–748. 197

Wolf, M. J., Emerson, J. W., Etsy, D., Wendling, Z. A. and et al (2022), ‘Environmental performance index 2022’.

URL: <https://epi.yale.edu/downloads/epi2022report06062022.pdf> 236, 239, 263

World Bank (2014), ‘Levelling the field: Improving opportunities for women farmers in africa’.

URL: <https://www.worldbank.org/en/region/afr/publication/levelling-the-field-improving-opportunities-for-women-farmers-in-africa> 122

World Bank (2019), *World development report 2020: Trading for development in the age of global value chains*, The World Bank. 1, 184

World Bank (2022), ‘Expanding african trade to boost growth and reduce poverty’.

URL: <https://www.worldbank.org/en/news/feature/2022/02/10/expanding-african-trade-to-boost-growth-and-reduce-poverty> 4, 5

World Bank (2024a), ‘World bank backs ethiopia’s reforms to promote sustainable and inclusive growth, enhance resilience, and take climate action’.

URL: <https://www.worldbank.org/en/news/press-release/2024/07/30/world-bank-backs-ethiopia-s-reforms-to-promote-sustainable-and-inclusive-afe-growth> 120

World Bank (2024b), ‘World Development Report 2024’. Accessed: 2024-10-11.

URL: <https://www.worldbank.org/en/publication/wdr2024> 142

World Meteorological Organization (2021), *State of the global climate 2020*, WMO. 1

Xin, Y., Tabasam, A. H., Chen, Z., Zamir, A. and Ramos-Meza, C. S. (2024), ‘Analyzing the impact of foreign direct investment, energy consumption on services exports, and growth of the services sector: Evidence from saarc countries’, *Journal of the Knowledge Economy* 15(2), 5709–5728. 3

Xu, X. and Sheng, Y. (2012), ‘Productivity spillovers from foreign direct investment: firm-level evidence from china’, *World Development* 40(1), 62–74. 188

Yale Center for Environmental Law and Policy - YCELP - Yale University, Center for International Earth Science Information Network - CIESIN - Columbia

- University, World Economic Forum - WEF, and Joint Research Centre - JRC - European Commission (2012), '2012 Environmental Performance Index and Pilot Trend Environmental Performance Index', *Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC)* .
URL: <https://doi.org/10.7927/H48913SG> 298
- Yale, Y. and CIESIN, C. (2022), '2022 environmental performance index (EPI)'.
URL: <https://doi.org/10.7927/dwt2-9k25> 239
- Yang, Y. (2005), 'Can the strengths of aic and bic be shared? a conflict between model identification and regression estimation', *Biometrika* **92**(4), 937–950. 155
- Yatchew, A. (1997), 'An elementary estimator of the partial linear model', *Economics letters* **57**(2), 135–143. 35, 44
- Yu, S., Hu, X., Fan, J.-l. and Cheng, J. (2018), 'Convergence of carbon emissions intensity across chinese industrial sectors', *Journal of Cleaner Production* **194**, 179–192. 293
- Yuan, R. and Keeves, J. P. (2001), 'The multilevel analysis of students' achievement in learning the chinese language.'. 149
- Zarsky, L. (1999), 'Havens, halos and spaghetti: untangling the evidence about foreign direct investment and the environment', *Foreign Direct Investment and the Environment* **13**(8), 47–74. 291
- Zerfu, E., Berhanu, D., Shiferaw, L. and al, e. (2024), 'Strengthening rural livelihoods through agricultural value chains in Ethiopia: evidence from integrated interventions', *Agriculture & Food Security* **13**(1), Article 10.
URL: <https://agricultureandfoodsecurity.biomedcentral.com/articles/10.1186/s40066-024-00470-8> 120
- Zhang, J. (2013), 'Literature review on ekc and the effects of fdi on the environment', *Foreign Direct Investment, Governance, and the Environment in China* pp. 49–62. 230, 234, 289, 290, 291, 292

- Zhang, K. and Wang, X. (2021), ‘Pollution haven hypothesis of global co₂, so₂, nox—evidence from 43 economies and 56 sectors’, *International Journal of Environmental Research and Public Health* **18**(12), 6552. [235](#)
- Zhang, Z., Yang, W., Li, D. and Wang, Y. (2023), ‘Impact of two-way fdi on china’s environmental quality: The perspective of environmentally cleaner production and end treatment’, *International Journal of Environmental Research and Public Health* **20**(5), 4320. [236](#)
- Zheng, D. and Shi, M. (2017), ‘Multiple environmental policies and pollution haven hypothesis: evidence from china’s polluting industries’, *Journal of Cleaner Production* **141**, 295–304. [230](#), [235](#)
- Zugravu-Soilita, N. (2017), ‘How does foreign direct investment affect pollution? toward a better understanding of the direct and conditional effects’, *Environmental and Resource Economics* **66**(2), 293–338. [235](#)