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How Do Remittances Influence the Mitigation of Energy Poverty in Latin America? An Empirical Analysis Using a Panel Data Approach

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Abstract: Energy poverty represents a critical challenge in Latin America today, given the social disparities the region faces. In this context, this study focuses on exploring the effects of remittances on the energy poverty of 13 Latin American countries during the period 2000–2020. Panel estimations with fixed and random effects, along with the generalized method of moments, are employed to address potential endogeneity issues. The results suggest that remittances play a significant role in mitigating energy poverty in the Latin American region, particularly in rural areas. Furthermore, it is observed that economic growth and financial development act as mediators, allowing remittances to indirectly contribute to mitigating energy poverty. Although inequality was examined as a potential mediator, the findings suggest that it does not play a significant role in this context. It is concluded that remittances are an appropriate mechanism to improve the quality of life of the population, and their impact is strengthened in a more robust economic environment.

Keywords: remittances; energy poverty; economic growth; international migration

JEL Classification: F24; I3; O40; D63

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1. Introduction

During the last decades, remittance flows sent by migrant workers have consolidated as one of the main sources of financing (Acosta et al. 2008; Konte 2018; Ekanayake and Moslares 2020). Globally, the amount of remittances has experienced significant growth, from around $100 billion in 1995 to over $740 billion in 2019 (Feld 2021). These sources of income are especially crucial for middle- and low-income countries, contributing 5.04% to GDP in 2020, surpassing other sources of financing such as Foreign Direct Investment (FDI) or official development aid (Ahmed et al. 2021). At the regional level, in 2022, the flow of remittances to Latin America and the Caribbean experienced the highest growth with 9.3% (Banco Mundial 2023). As a result, remittances in the Latin American region increased from 1.10% of GDP in 2010 to 2.58% of GDP in 2022. Central American countries such as Honduras, El Salvador, Haiti, and Nicaragua depend prominently on these remittance flows (Caruso et al. 2021). This steady growth in remittances has attracted considerable interest in the academic literature, which seeks to assess the extent of their effects on various economic and social aspects. Previous research has identified that remittances contribute to improving the stability of household consumption (Mondal and Khanam 2018; Otame 2023), reducing food insecurity (Mora-Rivera and van Gameren 2021), alleviating restrictions on access to financial resources (Fromentin 2017), promoting a more equitable distribution of income (Bang et al. 2016), and, in general, improving the quality of life of remittance recipient families (Feld 2022).

At the macroeconomic level, remittances have not only been shown to have an impact on economic growth (Bezabh and Kumar 2020), but have also played a significant role in poverty alleviation (Cui et al. 2023). Thus, a substantial body of literature has carefully studied the link between remittances and poverty. One of the first studies to analyze the impact of international remittances on poverty was conducted by Adams (1991). This study found that households in poverty decreased by 9.8% when the predictor of per capita household income included remittances sent from abroad. Thus, the literature has been expanding considerably. For example, Adams and Page (2005) examined the impact of remittances and migration on poverty in 71 developing countries. This study's findings showed that a 10% increase in per capita international remittances resulted in a 3.5% reduction in the number of people living in poverty. To date, research focused on this phenomenon continues to recognize the significant effect of remittances in combating poverty, the magnitudes of which vary according to the economic, social, and political structure of each context (Cui et al. 2023; Akobeng 2016; Saptono et al. 2022; Khan 2023a; Can and Can 2023).

Despite the growing interest in the literature on the impact of remittances on poverty, it is important to recognize that poverty is not limited solely to the absence of economic resources (Bao and Liao 2024). Previous research has focused mostly on poverty in its general form, neglecting specific aspects inherent to living conditions. One of the areas that have received minimal attention is the effect of remittances on energy poverty (Djeunankan et al. 2023), and it is precisely this aspect that this research aims to expand. Currently, fuel poverty is a complex concept due to its multidimensional approach (Abbas et al. 2022). In simple terms, fuel poverty could be defined as the lack of accessibility and availability of safe and reliable energy services (Huang et al. 2022). Energy poverty can result from the combination of different factors, such as households with low income levels and limited equity resources (Sharma et al. 2019; Mulder et al. 2023), energy-inefficient housing (Drescher and Janzan 2021), home ownership status and place of residence (Abbas et al. 2022; Taltavull de La Paz et al. 2022), low levels of education (Awan et al. 2022), and high energy costs (Sharma et al. 2019).

Globally, approximately 1200 million people, especially in rural areas, in 2022 did not have access to electricity (Barkat et al. 2023), and about 2300 million people relied on harmful fuels for cooking (World Health Organization 2023). This concern has mainly extended to developing countries, where the population still continues to experience difficulties in accessing reliable, quality, healthy, and environmentally friendly energy services (Sy and Mokaddem 2022). At the regional level, during 2022, Sub-Saharan Africa was positioned as the region with the largest energy deficit, where about 600 million people did not have access to electricity and less than 20% had access to clean cooking facilities (International Energy Agency 2022). On the other hand, Latin America has an average rate of access to electricity that exceeds 98%; however, behind this figure, there is a significant gap in terms of energy inequality (Thomson et al. 2022; Dehays and Schuschny 2019). In 2022, about 17 million people did not have access to electricity and 75 million did not have access to clean cooking fuels (Comisión Económica para América Latina y el Caribe 2022), which are harmful to human health (Huang et al. 2022). In addition, 15% of the population living in precarious conditions did not have access to electricity. This problem intensified in countries such as Bolivia, El Salvador, Honduras, Guatemala, and Nicaragua, where the figure was between 30% and 40% (Comisión Económica para América Latina y el Caribe 2022). According to Thomson et al. (2022), 64.8% of companies in the region experienced power outages, and in countries such as Brazil, 17.9% of the population had difficulty paying their electricity bills, reflecting problems of accessibility and shortcomings in the quality of electricity supply. It is in this context that remittances can play an important role in improving the economic conditions of recipient households, which could facilitate access, availability, and quality of energy sources. This situation aligns with the Sustainable Development Goals (SDGs), specifically SDG number 7, which focuses on "ensuring access to affordable, reliable, sustainable, and modern energy for all" (Büyüközkan et al. 2018, p. 210).

Given the global energy challenges, the objective of this research is to comprehensively address the relationship between remittances and energy poverty. In this context, this study addresses three key issues to strengthen the existing empirical evidence. First, according to what has been reviewed, there has been no evidence of previous work linking remittances and fuel poverty in Latin America, so this study seeks to fill this gap. Second, in order to deepen the implications of remittances, three possible channels through which remittances may indirectly affect energy poverty are explored: economic growth (real GDP per capita), financial development (domestic credit to the private sector granted by banks as a percentage of GDP), and income inequality (Gini index). Third, the direct effect of economic growth, financial development, income inequality, and urbanization on energy poverty is analyzed, extending the literature on determinants of energy poverty. To fulfill these purposes, this paper uses World Bank data (World Bank 2023) for 13 Latin American countries for the period 2000–2020. Methodologically, several models based on panel data are estimated by means of Ordinary Least Squares with fixed and random effects, as well as the Generalized Method of Moments (GMMs) to address possible endogeneity problems in the estimates, as suggested by Barkat et al. (2023).

The results highlight the important role of remittances in facilitating access to clean and modern energy sources, especially in developing regions such as Latin America. However, it is evident that the impact of remittances on energy poverty alleviation is more profound in rural areas. The current socioeconomic situation of these areas in the region is critical, with significant increases in poverty and extreme poverty levels (Economic Commission for Latin America and the Caribbean 2023). This trend has contributed to a widening of the gap between urban and rural areas, representing a major challenge for achieving the Sustainable Development Goals. In addition, it is noted that economic growth and financial development act as key mediators in the interaction between remittances and energy poverty. In this context, it is imperative to design mechanisms to efficiently take advantage of these channels, enabling remittances to generate positive effects on social dynamics and reverse disparities in the region.

This empirical study makes a significant contribution to the literature in two respects. First, it undertakes a comprehensive review of the literature on the impact of remittances on a specific aspect of poverty and its practical application. The innovation lies in the selection of different variables to measure energy poverty, providing rigor to the results obtained. Unlike empirical studies that evaluate the direct effect of remittances on poverty in Latin America (e.g., Acosta et al. 2008; Vacaflores 2018), this study not only addresses such an impact but also analyzes the possible channels through which remittances may indirectly affect energy poverty. Thus, it not only updates the empirical evidence but also provides some public policy recommendations. Second, this study provides valuable information on energy poverty by focusing on Latin America, a region characterized by constant instabilities in a broad framework that encompasses political, economic, and social dimensions. In summary, these two contributions give relevance to our contributions, which are essential for policy decision-makers, especially in the formulation of strategies and mechanisms aimed at mitigating energy poverty in the Latin American region.

The article is structured as follows: Section 2 discusses the literature review and research hypotheses. Section 3 describes the methodology and empirical strategy. Section 4 presents the empirical findings, and Section 5 presents some conclusions and recommendations.

2. Review of the Literature

2.1. Remittances and Energy Poverty—Implications of a Direct Link

Theory suggests that migrants send remittances to their countries of origin for altruistic reasons, self-interest, and security concerns (Agradi 2023). Given these motivations, it would be natural to assume that migrants send these resources in order to improve the economic conditions of their families in their home countries (Yoshino et al. 2020). Empirical studies have shown that remittances increase household welfare by 2% and reduce poverty

by 4% (Nanziri and Mwale 2023); therefore, poor households improve their ability to meet basic needs.

The direct impact of remittances can be explained by enabling recipient households to substantially increase their income, likely resulting in a significant decrease in people living below the poverty line (Feld 2022). Using a panel data set from 24 Asia–Pacific countries, Imai et al. (2014) support the premise that remittances directly contribute to poverty reduction by improving income levels. Following this line, Gupta et al. (2009), examining the flow of remittances to Sub-Saharan Africa, find that remittances alleviate budget constraints immediately in recipient households. In Ghana, Adams and Cuecuecha (2013) find that households receiving remittances increase their income directly, allowing them to expand their expenditures on education, housing and health.

Abduvaliev and Bustillo (2020), focusing on 10 former post-Soviet republics belonging to the Commonwealth of Independent States (CIS), reveal that a 1% increase in remittance flows leads to a 2% reduction in poverty severity. Using Ordinary Least Squares random effects estimations, Taghizadeh-Hesary et al. (2021) find that a 1% increase in international remittances, expressed as percentages of GDP, is associated with a 0.19% decrease in the poverty headcount index, a 0.3% decrease in the poverty gap index, and a 0.6% decrease in the poverty severity index in a sample of 12 Asian developing countries. Similarly, Cui et al. (2023) examine the effect of remittances on poverty alleviation in 15 Asian economies, finding a significant impact even after controlling for the indirect effect of different covariates. For the Middle East and North Africa (MENA) countries, Khan et al. (2022), using panel data estimates, conclude that for every 1% increase in remittances, the poverty rate is reduced by 0.66%, a relatively larger effect compared to the impact of foreign aid, which reduces poverty by 0.23%. However, research such as that of Acheampong et al. (2021b) finds that remittances increase poverty levels in 44 Sub-Saharan African countries because they retard economic growth and thus appear as compensatory transfers. Chea (2023), based on data from the 2014 Cambodia Socioeconomic Survey, finds that remittances reduce the poverty rate by 2% at the national level and by 5% in recipient households. Through an adjusted logistic regression model, Debnath and Nayak (2022) examine the effects of remittances on different socioeconomic aspects of households in Bancura district, in the western part of India. Their findings show that remittances are a successful strategy for marginalized households to resist chronic poverty and for better-off households to improve their quality of life. Nawaz et al. (2023) explore the impact of remittances on poverty alleviation in Tajikistan over the period 2010–2019, concluding that remittances are an important mechanism for reducing poverty. In the context of Kosovo's economy, Rexhepi (2023) finds that remittances allow increasing the welfare level of families, as these resources, being directed to both consumption and investment, alleviate poverty, increase employment and education, and improve health status. Regarding Latin America, Ekanayake and Moslares (2020), using panel least squares, fully modified least squares (FMOLS), and estimations under the Autoregressive Distributed Lag (ARDL-ECM) approach, find that remittances have significant effects in reducing poverty in the region. In contrast, Vacaflores (2018) evidences that, although remittances have a significant influence in reducing extreme poverty, they also exacerbate moderate poverty, although the latter effect is predicted to be weak.

Although there is abundant empirical evidence on the impacts of remittances on poverty in general, the question underlying the identified problem is: Is there a direct effect of remittances on energy poverty? Remittances could have an immediate effect on alleviating energy poverty through a significant increase in income that allows for an increase in adequate energy consumption. Kakhkharov et al. (2021) investigate the allocation of remittances to household expenditures in Uzbekistan. Their findings show that households tend to allocate most of their remittance income to non-food consumption. This idea is reinforced by the research of Rahman et al. (2021), who examine the effect of remittance income on energy consumption in the four highest remittance recipient countries in South Asia. Using dynamic panel estimations and causality tests, they find that a 1%

increase in remittance income causes a 0.045% increase in energy consumption. Moreover, the intensity of this effect tends to increase in countries such as Bangladesh and Pakistan, which are characterized by high poverty rates. In Jamaica, Das and McFarlane (2022), applying an error correction model, find that in both the short and long run, increases in remittance flows are positively related to electricity consumption and negatively related to electricity loss. Using cointegration techniques, Sahoo and Sethi (2022) assess whether remittance inflows to India stimulate electricity consumption. Their empirical results provide evidence that remittances increase electricity consumption, becoming an important basis for India's growth. On the other hand, Lokonon (2020) empirically investigates some factors associated with the choice of cooking fuels in Beninese households. Among his results, he highlights the fact that remittances are positively associated with the adoption of modern cooking fuels.

Recent literature has begun to investigate the specific effects of remittances on energy poverty. Subramaniam et al. (2023) study the role of remittances in moderating the energy security-poverty nexus in 50 developing countries. By applying the Generalized Method of Moments (GMM), their results reveal that remittances help to alleviate energy poverty, facilitate energy access, and enhance energy security. Hosan et al. (2023), through the household income and expenditure survey in Bangladesh, explore the impact of remittances on energy poverty and find that an increase in remittances has a positive impact on alleviating energy poverty. Barkat et al. (2023), analyzing 109 low- and middle-income countries, conclude that remittances are an effective channel for reducing energy poverty. Djeunankan et al. (2023) provided evidence that remittances have a significant impact on reducing energy poverty in 79 developing countries, where economic growth and education play a key role as transmission channels through which remittances generalize their impact. Agradi (2023) evidences, through marginal effects, that a 1% increase in the flow of remittances increases electricity consumption by 0.5 to 0.8%, which helps to combat energy poverty in Africa. Table 1 below summarizes the most relevant research reviewed in this subsection.

Table 1. Summary of some studies on remittances and poverty.

Author	Country(ies), Data, Methodology	Endogenous Variable	Independent Variable(s)	Conclusion
Abduvaliev and Bustillo (2020)	Commonwealth of Independent States (CIS); 1998–2016; random-effect, fixed-effects, least squares models (OLS) with and without instrumental variables.	Economic poverty	Remittances	Remittances reduce economic poverty.
Taghizadeh-Hesary et al. (2021)	Twelve Asian developing countries; ordinary least squares (OLS); 1981–2018.	Economic poverty	Remittances	Remittances reduce economic poverty.
Cui et al. (2023)	15 Asian economies; 2000–2020; panel data estimates.	Economic poverty	Remittances	The asymmetric effect of remittances on poverty reduction.
Rahman et al. (2021)	South Asian countries; 1976–2019; fully modified ordinary least square, vector error correction model (VECM), and Granger causality.	Energy consumption	Remittances	Remittances lead to an increase in energy consumption.
Das and McFarlane (2022)	Jamaica; 1976–2014; vector error correction model (VEC) and Granger causality.	Electricity consumption; Electricity loss	Remittances	Positive effect of remittances on consumption of electricity and negative effect on electricity loss.

Table 1. *Cont.*

Author	Country(ies), Data, Methodology	Endogenous Variable	Independent Variable(s)	Conclusion
Hosan et al. (2023)	Bangladesh; 2016; two-stage least squares and logistic regression.	Multidimensional energy poverty	Remittances	Remittances contribute to reducing multidimensional energy poverty.
Barkat et al. (2023)	109 developing countries; 2000–2019; panel fixed and random effects; system generalized method of moment.	Energy poverty	Remittances	Remittances alleviate energy poverty.
Agradi (2023)	Africa; 1991–2917; dynamic common correlated effect pooled mean group instrumental variable (DCCE-PMG IV).	Energy poverty	Remittances	Remittances reduce energy poverty.
Djeunankan et al. (2023)	79 developing countries; 2000–2019; fully modified ordinary least square; and the dynamic ordinary least square.	Energy poverty	Remittances	Remittances help reduce energy poverty.

Based on the literature review, the first hypothesis of this research is formulated as follows.

Hypothesis 1 (H1): *Remittances have a direct and significant impact on reducing fuel poverty.*

2.2. Remittances and Fuel Poverty: Through Which Channels Can Remittances Alleviate Fuel Poverty?

Particularly, the empirical literature argues that remittances not only directly influence poverty alleviation, but there are other channels through which remittances can potentially affect poverty (Agradi 2023). Following Barkat et al. (2023) and Hosan et al. (2023), three well-documented channels through which remittances intensify their effects are explored below.

2.2.1. Linking Remittances, Economic Growth, and Energy Poverty

The link between remittances and economic growth continues to be the subject of a debate that lacks a definitive consensus. On the one hand, several studies indicate that remittances contribute to economic growth through their positive impacts on consumption, investment, and savings (see, for example, Meyer and Shera 2017; Golder et al. 2023; Villanthenkodath and Ansari 2023; Klaiqi et al. 2023; Khan 2023b; Bucevska 2022; Pal et al. 2022; Dutta and Saikia 2022). On the other hand, there is research suggesting that remittances can have a positive effect in the short term but that a permanent transfer of these resources does not necessarily translate into sustainable output growth (Batu 2017; Qutb 2022). In addition, there are studies that describe that remittances have an ambiguous (Zardoub and Sboui 2023) and/or negative effect on macroeconomic aspects, leading to asymmetries in the economy. They argue that, as they are mainly earmarked for immediate consumption rather than productive activities, they may slow down economic growth (Nyasha and Odhiambo 2022; Offor et al. 2023).

Regarding the impact of economic growth on poverty, there are a variety of current studies that support the idea that economic growth remains a necessary condition for reducing poverty in its most general aspect (see, for example, Ngubane et al. 2023; Balasubramanian et al. 2023; Kouadio and Gakpa 2022; Ochi 2023). Moreover, it has been evidenced that economic growth and renewable and non-renewable energy consumption are interconnected (Acheampong et al. 2021a). This fact reinforces the idea that economic growth can be a relevant means as a transmission channel to alleviate energy poverty.

However, given the divergent results found in the literature between remittances and economic growth, it seems necessary to further deepen the effects of remittances on fuel poverty through economic growth (Barkat et al. 2023). In a first inference, it could be assumed that an increase in economic growth due to remittances could stimulate energy consumption (Acheampong et al. 2021a), resulting in a decrease in energy poverty. However, if the effect is adverse, energy poverty could worsen (Barkat et al. 2023). Table 2, summarizing the most relevant research in this subsection, is presented below.

Table 2. Summary of some studies on economic growth and poverty.

Author	Country(ies), Data, Methodology	Endogenous Variable	Independent Variable(s)	Conclusion
Ngubane et al. (2023)	South Africa; 2000Q1–2021Q4; autoregressive distributed lag (ARDL) and autoregressive distributed lag (NARDL) models.	Food poverty	Gross domestic expenditure; unemployment rate	Economic growth reduces poverty in the long run.
Balasubramanian et al. (2023)	91 low- and middle-income countries; 1990–2018; first difference estimates (FDE).	Multidimensional poverty	GDP per capita	A 10% increase in GDP reduces multidimensional poverty by 4% to 5%.
Kouadio and Gakpa (2022)	West Africa; Pool Mean Group (PMG).	Household final consumption per capita	Real GDP per capita; institutional variables	Economic growth reduces poverty.
Ochi (2023)	45 sub-Saharan African countries; 2010–2021; generalized method of moment estimation at first differentiation.	Extreme poverty	Income inequality and economic growth	Growth reduces extreme poverty from an inequality threshold.

Based on the literature review, the second research hypothesis is formulated as follows:

Hypothesis 2 (H2): *Remittances through economic growth have a negative impact on fuel poverty.*

2.2.2. Linking Remittances, Income Inequality, and Fuel Poverty

Empirical research on the impact of remittances on income inequality has not generated conclusive results. Some studies conclude that remittances contribute to improving household quality of life by reducing income inequality (see, for example, Feld 2022; Azizi 2021; Mallick et al. 2020; Akim and Robilliard 2020; Bang et al. 2016). In contrast, other research suggests that remittances may increase income inequality (Arapi-Gjini et al. 2020; Ofori et al. 2022). According to Song et al. (2021), the effect of remittances on inequality depends on the income level of the recipient household. When poor and middle-class households are the main recipients of remittances, inequality tends to decrease, whereas when the recipients are rich households, inequality tends to increase. This pattern is related to the initial costs associated with the probability of migrating, limiting the ability of those with scarce economic resources (Barham and Boucher 1998).

On the other hand, the literature has documented that changes in poverty are linked to prior alterations in income inequality (Bergstrom 2022; Min and Rao 2023). In other words, inequality can play a key role in both mitigating and exacerbating poverty. However, some of the literature has examined the direct link between inequality and poverty, revealing that increases in income inequality intensify poverty status (Ibrahim and Taiga 2020; Adeleye et al. 2020). Following these findings, there has been a growing interest in research on the connection between income inequality and energy poverty. For example, Acheampong et al. (2022), using a panel of 43 sub-Saharan African countries between 1990 and 2017, found that income inequality significantly reduced access to electricity.

Given conflicting results on the relationship between remittances and income inequality, the indirect effect of remittances on energy poverty is not definitive. While remittances

generally increase income, their effects on inequality seem to depend on the financial structure of the recipient households. Table 3 below summarizes the most relevant research reviewed in this subsection.

Table 3. Summary of selected studies on remittances, income inequality, and poverty.

Author	Country(ies), Data, Methodology	Endogenous Variable	Independent Variable(s)	Conclusion
Mallick et al. (2020)	China and India; 1980–2013; autoregressive distributed lags (ARDL) models of Pesaran's cointegration approach.	Income inequality	Remittances	Remittances contribute to reducing income inequality.
Azizi (2021)	103 developing countries; 1990–2014; ordinary least squares (OLS) with fixed and variable effects.	Income inequality	Remittances	A 10% increase in remittances reduces the inequality gap by 1.8%.
Ofori et al. (2022)	42 African countries; 1996–2020; generalized method of moments (GMM).	Income inequality	Remittances	Remittances increase income inequality in Africa.
Acheampong et al. (2022)	43 sub-Saharan African countries; 1990–2017; two-step generalized method of moments (GMM).	Access to electricity	Income inequality	Income inequality increases energy poverty.

Based on the assumption that remittances can contribute to reducing income inequality, the third hypothesis of this research is formulated as follows:

Hypothesis 3 (H3): *Remittances, through their negative effect on income inequality, reduce energy poverty.*

2.2.3. Linking Remittances, Financial Development, and Fuel Poverty

Mohsin et al. (2022) found that 17.45% of Latin American residents did not reach the energy efficiency frontier. So they attribute energy poverty to low levels of financial development. Some studies support the fact that financial development is an important mechanism to mitigate poverty in general terms (Appiah-Otoo et al. 2022) and thus energy poverty (Dong et al. 2022; Mukhtarov and Mikayilov 2023). According to Rewilak (2017), further financial deepening, enabling marginalized sectors to access financial instruments, is listed as the most important category of financial development to alleviate poverty.

Due to the positive effects of financial development, the literature has focused on evaluating its determinants. In this sense, some studies have shown that remittances boost financial development, especially in developing countries (see, for example, Aggarwal et al. 2011; Gupta et al. 2009; Cooray 2012). For his part, Akobeng (2023) mentions that remittances help reduce poverty in environments with sound financial development. From these findings, it could be mentioned that remittances can reduce energy poverty through a more developed financial sector. Table 4 below summarizes the most relevant research reviewed in this subsection.

Table 4. Summary of some studies on financial development and poverty.

Author	Country(ies), Data, Methodology	Endogenous Variable	Independent Variable(s)	Conclusion
Appiah-Otoo et al. (2022)	16 West African countries; 2002–2019; fully modified ordinary least squares (FMOLS).	Household consumption per capita	Domestic credit to the private sector	Financial development reduces poverty.
Dong et al. (2022)	30 provinces of China; 2004–2017; generalized differential method of moments (Diff-GMM).	Energy poverty	Financial operations	Finance development helps eradicate energy poverty.
Mukhtarov and Mikayilov (2023)	Poland; 1990–2020; auto-regressive distributive lags (ARDL); and fully modified least squares (CCR and FMOLS).	Renewable energy consumption per capita	Domestic credit granted by banks to the private sector (% of GDP).	The development of the financial sector generates greater accessibility to adequate energy sources.

Based on the literature reviewed, the fourth hypothesis of this research is established as follows:

Hypothesis 4 (H4): *Remittances, through their positive effect on financial development, reduce energy poverty.*

2.3. Empirical Research Gap

The review of empirical studies reveals different effects of remittances on different economic variables interconnected with poverty in its general dimension. Furthermore, it has been observed that the magnitudes of their effects are asymmetric, underscoring the need to update this type of research. On the other hand, a consistent pattern has been identified: research tends to focus on capturing short- and long-term effects, neglecting equally significant aspects such as the mediating effects of key variables, including economic growth, income inequality, and financial development. These elements, recognized as essential by the literature, are a crucial focus that this study aims to address.

In addition, empirical studies have focused on specific regions, such as Africa and Asia, or have opted for the selection of broad panels covering developing economies in general. This trend has led to the conclusions obtained being generalized to less explored regions, such as Latin America. This region, characterized by constant instabilities, was particularly affected during the COVID-19 pandemic, generating a significant deterioration in social welfare, especially for economically vulnerable groups (Topcu 2022). The main gap identified is the lack of evidence documenting the impact of remittances on energy poverty in the Latin American region, a gap that this article seeks to fill in a comprehensive manner.

2.4. Measuring Fuel Poverty

As Sy and Mokaddem (2022) point out, a starting point for understanding fuel poverty and its measurement is to recognize the difficulty of providing a single definition. Some authors, such as Liang and Asuka (2022), have adopted two different concepts of "energy poverty". The first concept focuses on the affordability of clean and modern energy in developed regions, while the second focuses on the accessibility of adequate energy services in developing regions. According to Ugembe et al. (2022) and Suástegui et al. (2023), both concepts are relevant for measuring energy poverty due to different reasons. First, they do not restrict a specific form of energy. Second, affordability is a key concern, both in the developed and developing worlds. Third, the sustainability of the energy service depends on the accessibility and quality of the service.

According to Rodriguez-Alvarez et al. (2021), three different indicators of energy poverty can be distinguished. First, there is a subjective measure of a more qualitative type

based on household conditions, such as, for example, the inability to keep a home warm or physical damage to the structure of the dwelling (Aristondo and Onaindia 2023). Secondly, there is a direct measurement that compares the level of energy supply available to the household with the level of energy consumption in the home (Aristondo and Onaindia 2023); second, there is a direct measurement that compares the level of energy supply available in the household with an established threshold. According to González-Eguino (2015), any household below a minimum energy consumption is considered to be suffering from energy poverty (see, for example, Chidebell-Emordi 2015; Ye and Koch 2021).

Third, an approach based on households' economic expenditure on energy (see, e.g., Drescher and Janzan 2021). Within this category, the most common indicator is known as the "10 percent rule", which states that a household suffers from energy poverty if its energy expenditure exceeds 10% of its income (Pérez-Fargallo et al. 2023). Although this indicator seems simple to interpret, Awan et al. (2022) point out some limitations, including the sensitivity to energy prices (mainly fuels), the subjectivity of setting a poverty threshold without considering the overall socio-economic context, and the lack of a link to the household's income level. Another indicator within this category is "Low Income, High Cost" (LIHC), which assesses energy poverty by considering whether household income is below the monetary poverty line and energy expenditures are above a specific standard (Djeunankan et al. 2023). For example, Mulder et al. (2023) use the LIHC indicator, where the criteria for energy poverty include income below 130% of the social minimum (poverty line) and an energy contribution threshold of 8%. Another indicator used is "After Fuel Cost Poverty" (AFCP), which categorizes a household as energy poor if, after meeting housing and fuel expenses, it obtains a residual below the minimum necessary income (Awan et al. 2022).

In summary, there are a variety of indicators provided by the literature to measure and evaluate energy poverty. While indicators under the economic threshold approach would seem to be more convenient than those based on qualitative aspects (technological and physical threshold), they also present problems. According to Rodriguez-Alvarez et al. (2021), as these indicators are constructed from thresholds, the sensitivity to price shocks is greater, which could generate false positives. Qualitative indicators are constructed from microdata and require multidimensional indexes, which makes their applicability in macroeconomic studies more difficult.

3. Methodology

3.1. Data

To carry out the analysis and due to data limitations, an unbalanced panel of 13 Latin American countries is used, covering the period 2000–2020 (see Appendix A for the sample countries used). From the literature reviewed in Section 2, two approaches to measuring energy poverty stand out, which include (1) the economic threshold and (2) the physical threshold. First, the economic threshold relates to the affordability of energy, including modern energy services. Second, the physical threshold is associated with the affordability of minimum energy consumption (Djeunankan et al. 2023). According to González-Eguino (2015), these approaches are complementary, so more than one indicator is required to objectively measure energy poverty.

Recent studies use access to clean fuels and modern cooking technologies and access to electricity as indicators of energy poverty (Barkat et al. 2023; Djeunankan et al. 2023; Agradi 2023). These two indicators capture the affordability and accessibility aspects inherent in the concept of fuel poverty (González-Eguino 2015), which makes them two consistent measures. In fact, Djeunankan et al. (2023) suggest that these two indicators are suitable for conducting multi-country empirical studies. Based on these results, the present study uses three indicators of energy poverty as dependent variables: percentage of the total population with access to clean cooking technologies and fuels (EP1), percentage of the total population with access to electricity (EP2), and percentage of the rural population

with access to electricity (EP3). An increase in these indicators would reflect a reduction in energy poverty.

In this study, the independent variable focuses on workers' remittances sent to Latin America. Remittances are private transfers made by migrant workers to their families in their countries of origin (Yoshino et al. 2020). To measure their impact and economic importance, Barkat et al. (2023) suggest using workers' remittances as a percentage of GDP (RMT).

Following Barkat et al. (2023), Djeunankan et al. (2023), and Agradi (2023), to analyze the possible channels through which remittances can have an indirect impact on energy poverty, the following control variables are included as follows: the natural logarithm of GDP per capita in real terms to measure economic growth (EC), the Gini index as a proxy for income inequality (GINI), and domestic credit to the private sector granted by banks as an indicator of financial development (FD). To reduce bias due to possible omission of variables and based on the literature on the determinants of energy poverty (Cheikh et al. 2023), the urban population is incorporated as a percentage of the total population (PU). According to Mahumane and Mulder (2022), in urban areas, energy poverty has decreased because households have greater possibilities to increase energy consumption and access cleaner and more modern energy sources.

Table 5 presents a description, descriptive statistics, and the source of each variable. It is clear that there is a wide variability (standard deviation) among the countries analyzed in relation to poverty indicators. These values reflect a first impression of heterogeneity in the social structure throughout this study period. It is important to note that some Latin American countries have achieved 100% coverage in terms of the population having access to clean and modern energy, as well as access to electricity. In addition, there are countries in the region that have not developed a dependence on remittances, as they show minimal values of these flows that do not even represent 0.001% of GDP.

Table 5. Variables and descriptive statistics.

Variable	Description	Observations	Mean	Standard Deviation	Minimum	Maximum	Source
Energy Poverty (EP1)	Access to clean cooking technologies and fuels (% of the population)	273	80.90	17.65	30.30	100.00	World Bank (WDI)
Energy Poverty (EP2)	Access to electricity (% total population)	273	93.86	8.18	63.14	100.00	World Bank (WDI)
Energy Poverty (EP3)	Access to electricity (% rural population)	273	83.83	19.16	11.09	100.00	World Bank (WDI)
Remittances	remittances and employee compensation, received (% of GDP)	272	4.72	6.18	0.00	23.79	World Bank (WDI)
Economic growth	Ln real GDP per capita	273	8.67	0.58	7.48	9.77	World Bank (WDI)
Income inequality	GINI index	245	48.84	4.93	38.00	61.60	World Bank (WDI)
Financial development	Domestic credit to the private sector granted by banks (% GDP)	273	34.46	15.27	9.50	80.17	World Bank (WDI)
Urbanization	Urban population (% of total population)	273	73.11	12.26	45.46	95.52	World Bank (WDI)

Note: WDI data source refers to indicators obtained from the World Bank database (World Bank 2023). The logarithmic transformation is interpreted as elasticity.

3.2. Empirical Strategy

Following Djeunankan et al. (2023), the following empirical model relating remittances to energy poverty is specified:

$$Y_{jt} = f\left(RMT_{jt},\ X_{jt}\right) \tag{1}$$

where Y_{it} is the dependent variable and represents fuel poverty. This variable is a function of remittances (RMT) and a set of X control variables. According to Barkat et al. (2023), model (1), being a panel-based estimation incorporating fixed effects and random effects, can be specified as follows:

$$Y_{it} = \beta_0 + \beta_1 RMT_{it} + \beta_2 X_{it} + \mu_{it} + \varepsilon_{it} \tag{2}$$

where Y_{it} represents the three indicators selected to measure energy poverty, i denotes the country ($i = 1 \ldots .13$) and t denotes the period ($t = 2000, \ldots 2020$). RMT are the workers' remittances received by each country i in the Latin American region in a specific period t. X_{it} represent the selected control variables ($CE_{it}, GINI_{it}, DF_{it}, PU_{it}$). μ_{it} is a vector of dummy variables that captures the unobservable fixed effects per unit of analysis and ε_{it} is the stochastic disturbance term. As can be seen in Appendix B, most of the variables included in the analysis in their nominal form present skewness problems, suggesting variance stability issues. This situation could lead to biased, inefficient, and unreliable estimates. To improve this specification, the variables are transformed to logarithms, as suggested by the Box and Cox (1964) family. Thus, model (2) can be rewritten as follows:

$$Y_{it} = \beta_0 + \beta_1 RMT_{it} + \beta_2 CE_{it} - \beta_3 GINI_{it} + \beta_4 DF_{it} + \beta_6 PU_{it} + \mu_{it} + \varepsilon_{it} \tag{3}$$

From model (3), it is expected that remittances, economic growth, financial development, and urbanization are positively associated with energy poverty indicators. While an inverse relationship between income inequality and energy poverty is expected, in this sense, the Gini index, which measures income inequality, is an indicator whose values lie between 0 and 1, where 0 represents perfect equality and 1 represents perfect inequality (Furman et al. 2019). Therefore, if an increase in inequality is generated, a fall in energy poverty indicators would be expected.

Since this is an unbalanced panel data model where there is an absence of observations in the time and cross-sectional dimensions, the question arises: which estimation is the most appropriate to control for unobservable heterogeneity across individuals? Following the work of Baltagi and Song (2006) and Barkat et al. (2023), the analysis starts with static estimations using ordinary least squares (OLS) with fixed and random effects. The fixed effects allow controlling by incorporating dummy variables captured in μ_{it}, the unobservable factors that are constant over time but vary in the cross section due to country-specific characteristics. In other words, they control for the problem of heterogeneity, which can cause biased and inefficient estimates (Wooldridge 2010).

Subsequently, the robustness of the estimates is verified by applying a GMM (generalized method of moments) system approach. This method is used to control for both serial correlation and cross-sectional dependence in the data. Given the absence of lagged variables in the static model, there is the possibility of correlation between regressors and error terms, as well as the risk of omission bias. In addition, the presence of random effects could result in a non-constant variation of the residuals in both the time and cross-sectional dimensions of the panel data, generating, as well, serial dependence among the residuals and causing problems of heteroscedasticity and serial correlation (Wooldridge 2010). The GMM system method helps to address these challenges by introducing past differences as instruments for the levels (Khan et al. 2022).

Several studies investigating the relationship between remittances and poverty highlight the importance of addressing a possible endogeneity problem (Khan et al. 2022; Barkat et al. 2023; Subramaniam et al. 2023). Endogeneity is suspected due to the likelihood

of reverse causality between remittances, fuel poverty, and different control variables. Musakwa and Odhiambo (2021) found unidirectional causality running from poverty to remittances when using non-economic indicators to measure the poverty level. On the other hand, Usman (2023), using Granger causality tests, evidenced a bivariate causality between remittances and economic growth. These empirical studies reinforce the suspicion of endogeneity. In addition, there is the possibility of dynamic endogeneity caused by the relationship with past values. In this sense, when the country suffered from energy poverty in previous periods, it was possible that migrants transferred a larger amount of remittances to mitigate this problem (Barkat et al. 2023). Given these concerns, the GMM system is well-suited to address these problems.

Finally, to empirically determine the indirect effect of remittances on energy poverty through the three channels described in Section 2.2, we employ the two-stage estimation approach used in the studies of Barkat et al. (2023) and Djeunankan et al. (2023) using the GMM system. In the first stage, a correlation analysis is performed between remittances and each of the channels: economic growth (measured by real GDP per capita), income inequality (measured by the GINI index), and financial development (measured by credit to the private sector as a percentage of GDP). If the correlations are significant at a standard level (usually at 5%), we proceed with the second stage, which consists of regressions of remittances with each of the energy poverty variables. If, by including the mediating variable, the magnitude of the effect of remittances decreases or becomes statistically non-significant, then the channel is positioned as an effective link through which remittances indirectly affect fuel poverty.

4. Results and Discussion

4.1. Empirical Relationship between Remittances and Energy Poverty

Table 6 summarizes the effect of remittances on three indicators of energy poverty in Latin America using panel estimations with fixed and random effects. In model 1, we present estimates related to energy poverty, which is measured through access to clean cooking technologies and fuels. The Hausman test, found at the bottom of Table 6, indicates that the random effects approach is the most appropriate for this model (p-value > 0.05). In model 2, we present estimates for energy poverty as measured by the percentage of the total population with access to electricity. The Hausman test suggests that the fixed effects estimator is the most consistent for this model (p-value < 0.05). Finally, model 3 provides estimates for energy poverty based on the percentage of the rural population with access to electricity. The Hausman test also supports the use of the fixed effects approach as a technique for this model (p-value < 0.05).

In model 1, we observe that the estimated coefficient of remittances is positive and highly significant. This implies that a one percentage point increase in remittances relative to GDP is associated with an average increase in access to clean cooking technologies and fuels ranging from 0.071 to 0.081 percentage points. Regarding model 2, the estimated coefficient of remittances is also positive and highly significant, although with a slightly smaller magnitude compared to model 1. This result implies that access to electricity by the total population would increase in a range between 0.039 and 0.048 percentage points for every 1% increase in remittances. Finally, the estimator of model 3 suggests that the coefficient of remittances is positive and highly significant. Compared to models 1 and 2, the estimated coefficient shows a considerably higher magnitude. Therefore, it would be considered that for each percentage point increase in remittances, access to electricity by the rural population would increase by between 0.166 and 0.195 percentage points. These results underscore the fundamental role of remittances received by households in the Latin American region in improving the affordability and accessibility of modern and adequate energy sources, which in turn improves the quality of life and thus reduces energy poverty. It is important to note that remittances have a significant impact in rural areas, where energy demand is high but access to efficient energy structures is limited (Bai et al. 2023).

Table 6. Effects of remittances on fuel poverty.

	Model 1		**Model 2**		**Model 3**	
Dependent Variable	**EP1**		**EP2**		**EP3**	
Independent Variables (In Logarithms)	**Fixed Effects**	**Random Effects**	**Fixed Effects**	**Random Effects**	**Fixed Effects**	**Random Effects**
Remittances	0.080 *** (0.011)	0.071 *** (0.011)	0.048 *** (0.008)	0.039 *** (0.007)	0.193 *** (0.035)	0.166 *** (0.029)
Economic growth	0.242 *** (0.051)	0.273 *** (0.049)	0.090 ** (0.037)	0.131 *** (0.028)	1.140 *** (0.158)	0.958 *** (0.118)
Income inequality	−0.372 *** (0.081)	−0.320 *** (0.079)	−0.40 *** (0.059)	−0.327 *** (0.053)	−0.787 *** (0.248)	−0.832 *** (0.220)
Financial development	0.090 *** (0.017)	0.076 *** (0.016)	0.009 (0.012)	0.001 (0.010)	0.0107 (0.052)	0.0441 (0.043)
Urbanization	0.008 (0.107)	0.052 (0.105)	0.158 ** (0.08)	0.140 ** (0.069)	−1.265 *** (0.328)	−0.997 *** (0.289)
Constant	3.319 *** (0.669)	2.71 *** (0.643)	4.57 *** (0.486)	4.041 *** (0.406)	2.866 (2.055)	3.323 ** (1.703)
Observations	245	245	245	245	245	245
R square	0.69	0.69	0.63	0.63	0.56	0.56
Number of groups	13	13	13	13	13	13
Country and time fixed effects	YES		YES		YES	
[a] Hausman Test		10.01		16.14		11.99
Prob. Hausman Test		0.075		0.0064		0.0349
Best model		YES	YES		YES	
Wooldridge test		Prob < 0.05		Prob < 0.05		Prob < 0.05

Note. Standard error in parentheses: *** $p < 0.01$, ** $p < 0.05$. [a] Hausman Test for the specification of the most efficient estimators, H0: Best random effects model.

Regarding the control variables in model 1, the estimators present the expected signs according to the literature reviewed. Economic growth and financial development present positive and significant coefficients, implying that for each percentage point increase in these variables, access to clean cooking technologies and fuels increases by 0.273 and 0.076 percentage points, respectively. However, urbanization, although showing the appropriate sign, is not significant in this context. On the other hand, the estimated Gini coefficient is negative and highly significant, suggesting that a one percentage point increase is associated with a 0.320 percentage point decrease in access to clean cooking technologies and fuels. This means that a higher level of inequality aggravates energy poverty levels in the region.

The estimated coefficients of the control variables in model 2 remain consistent with theory and empirical implications. In this sense, economic growth, financial development, and urbanization are positively and significantly associated with access to electricity by the total population. From these results, the role of urbanization stands out, where for each percentage point increase in urbanization, the population with access to electricity increases by 0.158 percentage points, which is higher than the effect generated by economic growth (0.09%) and financial development (0.009%). On the other hand, a 1% increase in inequality is related to a 0.40 percentage point reduction in the population with access to electricity.

Finally, in model 3, the control variables show the expected signs except for urbanization. It is observed that a one percentage point increase in urbanization is associated with a reduction of between 0.997 and 1.265 percentage points in the rural population with access to electricity. This finding has important implications, mainly by highlighting a possible inequality gap in access to energy services. According to Yawale et al. (2023), a plausible explanation for this result is that an accelerated increase in energy demand in urban areas may result in the energy structure being concentrated in this sector, leaving rural populations at a disadvantage. In other words, electricity supply would be directed mainly to the areas with the highest urban concentration, which would make access to electricity service more difficult in areas farther away from cities.

However, according to the results in Table 6, the Wooldridge test yielded values below 5%, indicating the presence of serial autocorrelation. To address this problem and strengthen the robustness of the findings, we chose to estimate a GMM model using instrumental values. Following the recommendations of Ogaki (1993), endogenous and explanatory variables in their conjunctural and lagged forms are used as instrumental variables. After applying this correction, the results in Table 7 show that the Arellano-Bond test is above 5%, indicating that the autocorrelation problem has been corrected. Additionally, the Hasen test presents extremely high values, validating the suitability of the instruments used in the estimation.

Table 7. Estimation by means of the GMM System.

	Model 1	**Model 2**	**Model 3**
Dependent Variable	**EP1**	**EP2**	**EP3**
Remittances	0.018 **	0.018 ***	0.033 **
	(0.007)	(0.004)	(0.013)
Economic growth	0.19 **	0.13 **	0.38 **
	(0.08)	(0.051)	(0.17)
Income inequality	−0.016	−0.16 **	−1.007 **
	(0.12)	(0.072)	(0.405)
Financial development	0.07 **	0.05 ***	0.109 *
	(0.023)	(0.015)	(0.06)
Urbanization	0.60 **	0.103	−0.23
	(0.22)	(0.162)	(0.61)
Constant	−0.09	3.36 ***	5.61
	(1.02)	(0.766)	(3.42)
Observations	245	245	245
Number of groups	13	13	13
Number of instruments	18	17	17
Pro-F	prob < 0.05	prob < 0.05	prob < 0.05
Arellano-Bond test for AR(2)	0.063	0.201	0.267
Hansen test	0.855	0.542	0.444

Note. Standard error in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In the three models estimated using the GMM System (Table 7), the results continue to be consistent. The estimated coefficient for remittances is positive, significant, and shows relative stability. This finding reinforces the fact that remittances promote access to clean and modern energy, thus contributing to the reduction of energy poverty. Moreover, their impact in rural areas remains the largest in magnitude. Economic growth and financial development generate a positive and significant impact, confirming their role as determinants of energy poverty. On the other hand, the estimated coefficient of income inequality is negative and significant in models 2 and 3. This shows how increases in income inequality are an important factor in aggravating poverty.

In general, the results of the estimates suggest that remittances can play a relevant role in mitigating energy poverty in the Latin American region. Their complementarity with other factors of the macroeconomic environment, mainly economic growth, financial development, and inequality, allows us to measure their effects at the social level.

4.2. Indirect Effects of Remittances on Fuel Poverty

The results presented in Tables 6 and 7 confirm the basic hypothesis that remittances reduce fuel poverty. This subsection analyzes the transmission mechanisms discussed in Section 2.2. To do so, we follow the work of Barkat et al. (2023), using a two-step approach to empirically determine the transmission channels.

Table 8 presents the results of the first stage of analysis, where the relationship between remittances and the mediating variables, economic growth, income inequality, and financial development, is evaluated. First, the goodness-of-fit of the estimates is highlighted. It

is important to note that the AR test (2) yields probabilities that exceed the standard significance level of 5%, indicating that there are no possible serial correlation problems in the models. Additionally, the Hansen test shows that the instruments used are robust since they present significantly high probabilities in all estimates.

Table 8. First stage: Correlation between remittances and the channels of transmission of the effect on energy poverty. GMM Model.

	(A)	(B)	(C)
Dependent Variable	**Economic Growth**	**GINI**	**Financial Development**
Independent variables			
Remittances	0.518 **	−0.019	0.048 **
	(0.183)	(0.020)	(0.017)
Economic growth (−1)	0.829 ***		
	(0.112)		
Income inequality (−1)		0.941 ***	
		(0.035)	
Financial development (−1)			1.01 ***
			(0.020)
Constant	1.110	0.236 *	−0.031
	(1.002)	(131)	(0.083)
Observations	260	217	260
Number of Groups	13	13	13
Pro-F	<0.05	<0.05	<0.05
[a] AR(2)	0.491	0.668	0.096
[b] Hansen test	0.316	0.965	0.445

Note. Standard error in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. [a] Arellano–Bond test (AR) to identify autocorrelation, H0: no evidence of serial correlation in model errors. [b] Hansen test for instrument validation, H0: the instruments incorporated in the model are valid.

Table 8 shows that remittances are positively and significantly related to economic growth and financial development. These results indicate that an increase in remittances received by Latin American households is associated with an increase in GDP per capita and financial development. The relationship between remittances and inequality is negative and not significant. Based on these results, economic growth and financial development are highlighted as possible potential channels that mediate between remittances and energy poverty. Inequality is discarded as a possible mediating channel between remittances and energy poverty in the region, thus rejecting the theoretical hypothesis formulated in Section 2.2.2.

Table 9 presents the results of the interaction between remittances and the variables selected in the first stage, in relation to the three fuel poverty indicators. With the exception of estimate (A) which relates remittances to access to clean cooking technologies and fuels, the AR test (2) shows significantly high probabilities, suggesting that there are no autocorrelation problems. In addition, the Hansen test for all estimates validates the adequacy of the instruments used to control for potential endogeneity problems.

In column (A) of Table 9, we observe that the estimated coefficient of remittances is positive and statistically significant when interacting independently with the three measures of energy poverty. This result strengthens the idea that remittances play a key role in alleviating energy poverty in Latin America by promoting greater access to clean and modern cooking fuels and increasing access to electricity. This supports the theoretical hypothesis put forward in Section 2.2, which suggests a direct effect of remittances on energy poverty.

Table 9. Second stage: Effect of transmission channels on energy poverty.

Dependent Variable	**Access to Clean Technologies and Fuels for Cooking (% of Population)**		
	(A)	**(B)**	**(C)**
Remittances	0.037 ** (0.010)	0.097 (0.065)	−0.1533 ** (0.038)
Economic growth		0.932 ** (0.40)	
Financial development			0.290 *** (0.06)
Constant	4.38 ***(0.030)	−3.77 (3.512)	3.48 *** (0.189)
AR(2) Hansen test	0.04 0.946	0.195 0.711	0.132 0.908
Dependent variable	Access to electricity (% total population)		
Remittances	0.043 *** (0.005)	0.133 (0.079)	0.043 (0.0315)
Economic growth		0.482 ** (0.186)	
Financial development			0.205 * (0.102)
Constant	4.52 *** (0.007)	0.265 (1.64)	3.823 *** (0.406)
AR(2) Hansen test	0.581 0.917	0.296 0.755	0.241 0.174
Dependent variable	Access to electricity (% rural population)		
Remittances	0.177 *** (0.013)	0.326 * (0.171)	0.0427 (0.0315)
Economic growth		1.05 * (0.498)	
Financial development			0.205 * (0.1022)
Constant	4.316 *** (0.029)	−5.07 (4.355)	3.823 *** (0.406)
AR(2) Hansen test	0.362 0.950	0.430 0.776	0.241 0.174

Note. Standard error in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In column (B) of Table 9, we see that the coefficient of remittances is no longer statistically significant when interacting with economic growth as a mediating factor for the three measures of fuel poverty. Instead, the estimated coefficient of economic growth is positively and significantly associated, albeit at a standard level of between 5% and 10%. This indicates that economic growth acts as an appropriate channel through which remittances can mitigate fuel poverty. Therefore, the theoretical hypothesis formulated in Section 2.2.1, which describes economic growth as a potential mediating factor for reducing energy poverty in Latin America, is supported.

Finally, in column (C) of Table 9, it is evident that the estimated coefficient of remittances, when interacting with financial development, becomes negative in relation to access to clean cooking technologies and fuels and is not statistically significant with respect to access to electricity. Meanwhile, financial development is positively and significantly associated, albeit at a standard level of between 5% and 10%, with greater affordability and accessibility to adequate energy. This result reveals that financial development acts as a mediating factor between remittances and energy poverty, which supports the theoretical hypothesis formulated in Section 2.2.3, which denotes financial development as a potential channel through which remittances can reduce energy poverty.

In a joint analysis of the results obtained using the two-stage methodology proposed in the study by Barkat et al. (2023), it is highlighted that the estimated coefficients of remittances are positive and significant for all three indicators of energy poverty. Moreover, it is observed that the effect of remittances is even more pronounced when related to the rural population with access to electricity. However, when mediating variables are introduced into the estimates, a decrease in the magnitude of the coefficients and their statistical significance is evident. This underlines the importance of the role of some factors, such as economic growth and financial development, in transmitting the effects of remittances on energy poverty. In contrast, inequality appears to play a secondary role in this context. These findings, although not definitive, raise pertinent questions about the effect of remittances on Latin American society.

4.3. Discussion of the Results

The findings obtained in this research show that workers' remittances sent to the Latin American region are a fundamental factor in alleviating energy poverty in terms of affordability and accessibility. Following Agradi (2023), the positive effect could be due to the fact that remittances allow low-income households to overcome affordability problems, enabling them to increase their consumption of clean and adequate energy. Furthermore, Zhu et al. (2022) emphasize that energy consumption is closely related to household characteristics and conditions. In this sense, families can take advantage of remittances to invest in physical improvements to their homes and equipment, which will allow them to have better access to electricity and clean fuels for cooking. This argument is consistent with the study by Jayaweera and Verma (2023).

Another way in which remittances can play a key role is in paying for energy services. According to Saliou Barry and Creti (2020), households spend about 29% of their monthly income on paying for electricity services, reflecting the high-cost burden of this service. Thus, families with economic difficulties experience delays in paying their electricity bills, resulting in power outages. Remittances, by improving income levels, make it possible for families to pay for this service and have continuous energy.

A relevant finding of this research shows that workers' remittances have a significantly greater impact in rural areas compared to the total population. This result is consistent with the study by Barkat et al. (2023). According to Liu et al. (2023), it is common for rural areas to experience deficiencies in energy infrastructure, which in turn makes it more expensive and limits the energy consumption of this population. In addition, Wang et al. (2022) note that generally low-income people tend to be concentrated in rural areas, which further hinders their access to adequate energy sources. In this context, remittances contribute significantly to increasing the wealth of these communities, allowing them to overcome affordability and accessibility constraints in their energy consumption.

Finally, this research documents that economic growth and financial development are two potential channels through which remittances can mitigate energy poverty in the region. Like Barkat et al. (2023), this result is highly relevant, as it encourages governments to implement macroeconomic policies that help reduce energy poverty. In this sense, it is important that the government's actions are directed towards improving and strengthening the electricity grid and promoting efficiency in terms of energy transmission costs. This will promote the effect of remittances to be amplified and help households have full access to adequate and quality energy sources.

5. Final Conclusions and Recommendations

Remittances have been extensively researched in both theoretical and empirical studies and have been linked mainly to a mechanism to improve the quality of life of beneficiary families. There are strong reasons to believe that workers' remittances can contribute to reducing poverty in its different dimensions. In this context, the present study aims to explore the influence of workers' remittances on energy poverty in Latin America. Energy poverty was measured through three indicators: access to cooking technologies and fuels

(% total population), access to electricity (% total population), and access to electricity (% rural population). The explanatory variable used was workers' remittances as a percentage of GDP. Following Barkat et al. (2023) and Djeunankan et al. (2023), three potential channels through which remittances can have indirect effects on energy poverty were also explored: economic growth (real GDP per capita), financial development (domestic credit to the private sector granted by banks as % GDP), and income inequality (Gini index).

Taking as main reference the work of Barkat et al. (2023), three models were estimated under fixed and variable effects to capture the direct effect of the variables on the fuel poverty dimensions. In addition, a Generalized Method of Moments (GMM) estimation was performed to provide robustness to these estimates and correct for autocorrelation and endogeneity problems. In addition, a two-stage GMM system was estimated to evaluate the transmission channels. The data used covers the period 2000–2020 and comes from 13 Latin American countries. In general terms, the estimates present a good fit and statistical significance, which reinforces the findings of this study.

The empirical results showed that workers' remittances in general have contributed to mitigating energy poverty in Latin America. It is worth noting that this effect is even greater in rural areas, underscoring the importance of these resources for those households within the thresholds of economic vulnerability. In addition, the findings suggest that economic growth and financial development are two potential mediating channels through which remittances can indirectly influence energy poverty reduction, particularly in terms of affordability and accessibility. On the other hand, the inequality channel appeared to play a secondary role in this context.

Despite having obtained solid results, this study has some limitations that justify further research in this field. First, energy poverty is a multidimensional problem with structures and heterogeneities at the macroeconomic and microeconomic levels. In this sense, this study focused its attention on three fuel poverty indicators, leaving aside other indicators that could capture additional aspects of this social phenomenon. Second, the limited availability of information led to the selection of 13 Latin American countries, which could have left certain gaps in the cross-sectional section of this study. Third, only three possible mediating channels were addressed to avoid overloading the methodological specifications, despite the existence of other channels to be evaluated, such as state institutionality, human capital, and energy price shocks, among others. Finally, the estimates focused on short-term effects, suggesting the need for further research on long-term relationships.

Although workers' remittances have a significant effect on reducing energy poverty in Latin America, there is an important variation in the magnitude of this impact between urban and rural areas. Rural areas show an even greater dependence on remittances to overcome energy poverty, which evidences the need for specific public policies for these communities, such as programs aimed at improving energy infrastructure in rural areas, expansion of electricity grids, promotion of renewable energy technologies, and energy efficiency education and awareness programs. Governments could also establish specific funds with favorable interest rates and flexible terms to support local initiatives to finance community energy projects in rural areas.

Additionally, the long-term sustainability of energy infrastructure needs to be addressed. In this regard, policies should evolve to not only rely on remittances but also encourage domestic and foreign investments in sustainable infrastructure, leveraging remittances as an initial impetus. Governments could implement fiscal and financial incentives to stimulate local investment in sustainable energy projects, leveraging remittances. This could diversify energy sources and strengthen resilience to possible fluctuations in remittances. Financial education programs could also be implemented for remittance-recipient families. This could promote a more effective use of these resources, boosting not only affordability but also efficiency in access to energy services. At the same time, these efforts should be geared towards achieving the Sustainable Development Goals (SDGs).

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Appendix A. Sample of Countries Used in this Study

Table A1. Latin American countries selected for this study.

List of Countries Considered in the Research			
Argentina	Costa Rica	México	Uruguay
Bolivia	República Dominican	Perú	
Brazil	Ecuador	Paraguay	
Colombia	Honduras	El Salvador	

Appendix B. Normality Analysis of the Variables in Their Levels

The results in Table 6 show extremely low probabilities for the variables at their levels (with the exception of the natural logarithm of real GDP per capita), which is evidence to reject the null hypothesis that the variables are distributed asymmetrically.

Table A2. Normality analysis of the variables in their levels.

Variable	Description	Obs	Pr (Skewness)	Pr (Kurtosis)	adj chi2 (2)	* Prob > chi2
Energy Poverty (EP1)	Access to clean cooking technologies and fuels (% of the population)	273	0.0000	0.4839	31.07	0.0000
Energy Poverty (EP2)	Access to electricity (% of the total population)	273	0.0000	0.0000		0.0000
Energy Poverty (EP3)	Access to electricity (% of the rural population)	273	0.0000	0.0000		0.0000
Remittances	Workers' remittances and employee compensation, received (% of GDP)	272	0.0000	0.0007	61.48	0.0000
Economic growth	Ln Real GDP per capita	273	0.2293	0.0000	17.37	0.0002
Income inequality	GINI index	245	10.000	0.0196	5.44	0.0657
Financial Development	Domestic credit to the private sector granted by banks (% of GDP)	273	0.0072	0.0000	20.62	0.0000
Urbanization	Urban population (% of total population)	273	0.9220	0.0000	16.57	0.0003

* Note: The null hypothesis refers to the variables following a symmetrical distribution.

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