Migrant Remittances, Sustainable Development Goal (SDG) 7 and Energy Poverty in Sri Lanka

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Abstract

Modern, clean energy is seen as the golden thread that connects economic growth, human development, and environmental sustainability. However, almost 2.4 billion people worldwide still use solid fuels for cooking, exacerbating energy poverty and endangering human health and the environment. Therefore, this thesis investigated the non-price determinants of cooking fuel choice, including the causal relationship between migrant remittances and both cooking fuel choice and energy poverty. Sri Lanka was used as a case study, using more than 78,000 households from four waves of the Household Income and Expenditure survey from 2009 – 2019. Specifically, this thesis includes three empirical studies and one policy paper related to remittances and energy consumption.

The first study found that household income, household wealth, household head's characteristics (age, marital status and education), education of spouse, household characteristics (household size and number of children under 5), housing characteristics (number of bedrooms, drinking water source, and housing material), and residential sector (urban vs rural) were significant for selecting clean fuel for cooking, using multinomial logistic analysis. Moreover, the Advanced sustainability analysis showed a strong synergy between SDG 7 (clean energy), SDG 6 (Clean water), and SDG 4 (quality education).

The second study investigated the relationship between migrant remittances and cooking fuel choice by taking household wealth as a mediating variable. Using the propensity score matching method the study found that migrants used about 5.7% more clean fuels for cooking than non-migrant households. Furthermore, the control function approach found that a 1% increase in remittances increased clean cooking fuel use by 0.034 units, and instrumental variable (IV) mediation analysis indicated that household wealth significantly mediated this relationship.

The third study further explored the link between migrant remittances and energy poverty, using income inequality as the mediating variable. Two-Stage-Least-Squares (2SLS) regression results showed that a 10% increase in remittances decreased energy poverty by 0.042 units, while IV mediation analysis indicated that income inequality significantly mediated this relationship.

The final study examined the causes and economic implications of Sri Lanka's current energy crisis, its effect on energy poverty and the attainment of SDG 7. Specifically, the findings of the second and third studies were used to forecast the impact of a decline in migrant remittances of 40% due to the crisis on clean cooking fuel use and energy poverty. A 40% drop in remittances could reduce clean cooking fuel consumption by 0.16 units and increase energy poverty by 0.0016 units. The study concluded that Sri Lanka should encourage migrant remittances to enhance the use of clean cooking fuels and minimize energy poverty in light of the current energy crisis.

Notes on Publications

Chapter 2 published:

Wijayarathne, J. M. D. S., Hassan, G. M., & Holmes, M. J. (2023). Clean energy, Clean Water, and Quality Education: Prospects of Achieving Sustainable Development Goals (SDGs) in Sri Lanka. Natural Resources Forum, 1– 22. https://doi.org/10.1111/1477-8947.12287

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Chapter 4 currently review and resubmit :

Wijayarathne, J.M.D.S., Hassan, G., & Holmes, M. Migrant Remittances, Income Inequality and Energy Poverty: A Pseudo Panel Approach. *The Journal of Economic Inequality*

Chapter 5 currently under review:

Wijayarathne, J.M.D.S., Hassan, G., & Holmes, M. Covid-19, Energy Crisis and Sri Lankan Economy: A Matter of Migrant Remittances? *Energy Policy*

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Glossary of Terms

ASA	Advanced Sustainability Analysis
BOP	Balance of Payments
CA	Current Account
CBSL	Central Bank of Sri Lanka
CF	Control Function
GDP	Gross Domestic Product
GSEM	Generalized Structural Equation Modelling
HIES	Household Income and Expenditure Survey
IEA	International Energy Agency
IV	Instrumental Variable
LPG	Liquefied Petroleum Gas
LMICs	Low and Middle-Income Countries
MEPI	Multidimensional Energy Poverty Index
MNL	Multinomial Logit Model
NELM	New Economies of Labour Migration
OLS	Ordinary Least Square
PCA	Principal Component Analysis
PSM	Propensity Score Matching
SDG	Sustainable Development Goal
SEM	Structural Equation Modelling
2SLS	Two-Stage-Least-Square

Chapter 1: Introduction

1.1 Background of the Study

The beginning of 2022 was marked by a global energy crisis for most economies, due to substantial disruptions in energy markets triggered by two unforeseen events: the coronavirus pandemic and Russia's invasion of Ukraine (Berahab, 2022; United Nations, 2020). The current energy crisis is significantly larger, deeper, and more complicated than previous ones because it has far-reaching negative consequences for households, businesses, and the entire economy. The most immediate impact of the energy crisis is an extraordinary hike in fuel prices and as a result, the poorest households are likely to suffer the most (IEA, 2022), because high energy prices increase household expenditures in two ways (Guan et al., 2023). First, increases in fuel prices directly increase household fuel bills such as electricity and Liquefied Petroleum Gas (LPG). Second, a rise in fuel prices raises consumption expenditures on essential items such as food due to higher production costs. For example, the current surge in fuel prices has raised the average cost of generating electricity by around 90%, with natural gas alone accounting for more than half of the increase, leading to greater production costs (IEA, 2022). As a result, there have been substantial negative effects on household energy consumption, and many people have switched from clean fuels like electricity, LPG, and solar power to solid fuels such as fuelwood, biomass, and crop residues to do their household chores.

This backward energy transition from clean to solid fuel has a greater negative impact on achieving Sustainable Development Goal (SDG) 7, which calls for universal access to affordable, reliable, and modern energy services by 2030. According to the IEA (2022), approximately 75 million people who recently gained access to electricity are likely to lose their ability to pay for it, and 100 million people may return to using solid fuel for cooking. Furthermore, they predict that most countries will not achieve SDG 7 by 2030 as only a very few countries without full access to electricity have targets to increase electricity access by 2030. This will be particularly tricky in the case of clean cooking fuels, because only 39 countries have a clean fuel target to meet by 2030, out of 128 countries that currently lack universal access to clean cooking fuel and technologies. This will result in greater use of solid fuels for cooking, which will be harmful to human health and environmental sustainability. For instance, incomplete combustion of solid fuels directly causes substantial indoor air pollution by producing carbon dioxide (CO_2), carbon monoxide (CO), particulate matter ($PM_{2.5}$), and other greenhouse gasses (Balakrishnan et al., 2018; Chattopadhyay, Arimura, Katayama, Sakudo, & Yokoo, 2021; Muller & Yan, 2018; Shupler et al., 2018). This indoor air pollution is potentially hundreds of times more harmful to human health than outdoor air pollution and accounts for 3.2 million deaths worldwide (IEA, 2022; Smith & Mehta, 2003). In addition, the extraction of fuelwood for cooking contributes to deforestation, threatening other ecosystem services such as wildlife habitats, local temperatures, and water filtration by adversely affecting environmental sustainability (Gebreegziabher, Mekonnen, Kassie, & Köhlin, 2012; Heltberg, 2005).

This reverse trend in the energy transition from clean to solid fuel has a significant negative impact not only on the achievement of SDG 7 but also on global energy poverty. Energy poverty is the inability to access adequate, affordable, reliable, high-quality, safe, and eco-friendly energy services (Reddy et al., 2000). Energy poverty has severe negative impacts on human health, education, well-being, and the environment (Awaworyi Churchill, Smyth, & Farrell, 2020; Sovacool, 2012; Zhang, Li, & Han, 2019). Energy poverty is directly linked to the affordability of clean energy (Hosan, Rahman, Karmaker, Chapman, & Saha, 2023; Igawa & Managi, 2022). As a result, poorer households in low and middle-income countries (LMICs) are more likely to experience energy poverty (González-Eguino, 2015; Igawa & Managi, 2022; Nguyen & Nasir, 2021). Most LMICs have implemented various measures to combat energy poverty, and migrant remittances play a particularly important role as an alternative financing source for energy services in those countries (Hosan et al., 2023). Migrant remittances are the financial and in-kind transfers made directly by migrants to their families in their countries of origin (IOM, 2019), and they are currently one of the most significant external income sources in the majority of LMICs (Hassan, 2020). Migrant remittances to LMICs totalled USD 589 billion in 2021, which was a 7.3% increase over the previous year (World Bank, 2021). Furthermore, remittance flows are a stable source of capital compared to the other kinds of private capital flows such as exports and foreign direct investments, because they do not depend on external factors like cyclical fluctuations and external shocks (Koechlin & Leon, 2007). As a result, migrant remittances are the most significant revenue generator for LMICs to enhance the use of clean fuels and thereby reduce energy poverty.

Although migrant remittances would be a significant source of finance to enhance clean cooking fuel choices and minimize energy poverty, only a few studies have been conducted to date to examine the association between the two (Agradi, 2023; Barkat, Alsamara, & Mimouni, 2023; Hassan, 2020; Hosan et al., 2023; Manning & Taylor, 2014). Moreover, these studies' conclusions about the mechanism by which remittances affect cooking fuel choice or energy poverty are still unclear. Furthermore, many empirical studies have been conducted to examine the factors that influence cooking fuel choice at the household level, but their findings differ significantly because different studies use different variables, research approaches, study contexts, and analysis models. As a result, knowledge about the drivers of energy choice and the transition at the household level is still questionable. Therefore, this thesis addresses three main research questions: (1) what are the non-price determinants of cooking fuel choice; (2) do migrant remittances affect the type of cooking fuel choice; and (3) do migrant remittances affect energy poverty.

1.2 Study Context

We selected Sri Lanka as the study context because it offers an appealing backdrop for examining energy concerns and their connection to migrant remittances for a variety of reasons. First, Sri Lanka is one of the nations that has received the most international attention in recent years due to its severe energy crisis. Sri Lanka's government has officially declared that the country is experiencing its worst energy crisis in 73 years (Khalid, 2022). According to The Guardian (2022), the country has endured the longest power outages in the world, lasting 13 hours per day, although Sri Lankans have 100% access to electricity. Moreover, the Sri Lankan government encourages people to cook with fuel wood or other dirty fuel alternatives even though 68% of Sri Lankans still lack access to clean cooking fuels and technologies. These statistics clearly show that Sri Lanka will fail to meet SDG 7 by 2030.

Second, worker remittances are one of the largest foreign exchange earnings in Sri Lanka. Remittances contributed more than 8% to the Gross Domestic Product (GDP) from 2012 to 2020. Despite the COVID-19 pandemic in 2021, remittances accounted for about 6.18% of Sri Lanka's GDP (CBSL, 2022a). Remittance income amounted to US$ 7103.9, 5419.5 and 3313.9 million, in 2020, 2021, and 2022, respectively. Workers' remittances have covered almost 80% of the annual trade deficit in Sri Lanka over the last two decades (CBSL, 2022b). Thus, remittance income is a significant source of income for most Sri Lankan households, which could be used for energy services.

Third, energy poverty is an unexplained concept in Sri Lanka. Therefore, measurements, discussions, and research on energy poverty are largely missing in the policy and public domain in Sri Lanka, suggesting further investigations are needed (Jayasinghe, Selvanathan, & Selvanathan, 2021). Furthermore, the majority of Sri Lanka's energy poverty is attributed to the use of solid cooking fuels (Jayasinghe et al., 2021; Wijayarathne, Hassan, & Holmes, 2022). However, there has been very little research on cooking fuel use at the household level in Sri Lanka, and none of the studies have used an econometrics specification model (Nandasena, Wickremasinghe, & Sathiakumar, 2012; Rajmohan & Weerahewa, 2010; Wickramasinghe, 2011).

Accordingly, Sri Lanka is the best case study for studying the determinants of cooking fuel choice, the relationship between migrant remittances and the type of cooking fuel used, and energy poverty. We used data from the four waves of the Sri Lankan Household Income and Expenditure Survey (HIES) which were conducted in 2009, 2012, 2016, and 2019. The Department of Census and Statistics in Sri Lanka conducts HIES every three years, which provides essential socioeconomic data on demographics, income, expenditure, school education, health, and household assets.

1.3 Chapter Summary

Sri Lankan households are experiencing moderate levels of energy poverty, with solid cooking fuels accounting for the greater part of this poverty (Jayasinghe et al., 2021; Wijayarathne, Hassan, & Holmes, 2022). As a result, understanding the factors that influence fuel type choice is critical. Many studies have investigated the determinants of cooking fuel choice (Acharya & Adhikari, 2021; Ravindra, Kaur-Sidhu, Mor, & John, 2019; Sharma, Ravindra, Kaur, Prinja, & Mor, 2020). However, there is substantial heterogeneity among empirical investigations, as different studies employ different variables, research methods, study contexts, and analysis models. Hence, the determinants of cooking fuel selection and the transition remain unclear. Therefore, in Chapter 2 we investigated the non-price determinants of cooking fuel choice in Sri Lanka. Following the literature, we used a variety of socio-economic, demographic, household and other housing factors that affect cooking fuel choices. We included household income, household wealth, the demographic characteristics of the head and spouse (such as gender, marital status, age, and educational level), household characteristics such as household size, number of children and number of females, and housing characteristics (the number of bedrooms, the type of wall, floor, and roof materials, the source of drinking water, and the type of toilets) as the independent variables.

Some of these variables are directly linked to specific SDGs. For instance, the choice of cooking fuel choice is related to SDG 7 (clean energy); education of the heads of households and their spouses relates to SDG 4 (quality education), and drinking water and sanitation facilities relate to SDG 6 (clean water). This implies that although each SDG focuses on different aspects, the majority of SDGs are integrated, indivisible, and create synergies. Regrettably, SDG interactions have inadequate conceptual and scientific underpinnings (ICSU, 2017). As a result, there is a lack of proper understanding of synergies, which will result in the creation of incoherent policies, delaying the SDG agenda's outcomes (Mainali, Luukkanen, Silveira, & Kaivo-oja, 2018). Therefore, there is a clear need to identify the inter-relationships of SDGs in promoting the SDG agenda more efficiently (Weitz, Carlsen, Nilsson, & Skånberg, 2018). As a result, Chapter 2 also identifies the synergy between SDG 7, 6 and 4.

To examine the determinants of cooking fuel choice and the synergy between SDGs, the study used 79,106 households, after removing data with missing values for variables relevant to the study. The random-effects panel multinomial logit results showed that household income, household wealth, age, marital status and education of the head, education of the spouse, household size, number of children, housing characteristics, and residential sector are vital in selecting clean fuel for cooking. Furthermore, advanced sustainability analysis indicated that SDG 4 and 6 have a strong synergistic effect on SDG 7. Accordingly, the findings contribute to the literature in two ways; (1) this is a pioneering study in exploring the synergies between SDGs 4, 6, and 7 using nationally representative data. A thorough understanding of SDGs' linkages will help to integrate different sector-specific programs and develop consistent cross-sectoral policies; and (2) this study adds to the literature by investigating the driving forces of cooking fuel choice, covering about 79,000 households. The results can help in the preparation of effective government policies for energy transition at the household level.

Aside from these variables, migrant remittances also influence the choice of cooking fuel in most countries, but few studies have been conducted to investigate this association (Hassan, 2020; Manning & Taylor, 2014; Taylor, Moran-Taylor, Castellanos, & Elías, 2011; Ye & Koch, 2021). No study has established a clear link between migrant remittances and clean fuel usage because many factors drive the use of remittances. For example, remittance is a flow variable rather than a stock, and therefore, it may not promote clean energy spending directly even if it induces current expenditure. Thus, if energy spending is to be induced, it must be more closely related to stock variables like education, health and wealth (Hassan, 2020). Household wealth, as identified in Chapter 2, has a significant impact on clean cooking fuel choice, and it is a stock variable that would promote clean energy use through remittances. Much previous research also showed that migrant remittances substantially affect household wealth (Baiyegunhi & Hassan, 2014; Rahut, Behera, & Ali, 2016), and household wealth significantly influences clean fuel consumption (Adams & Cuecuecha, 2010; Mahapatro, 2016). As a result, Chapter 3 integrates two distinct pieces of literature: remittances and energy, through household wealth. Thus, in Chapter 3 we provide answers to three research questions: (1) does clean cooking fuel consumption differ between migrants and non-migrants; (2) do migrant remittances influence the type of cooking fuel used; and (3) does household wealth mediate the relationship between migrant remittances and the type of cooking fuel used.

To explore this, HIES data from 78,931 households were used, after removing rows with missing values for variables associated with the study. Propensity score matching analysis revealed that migrants used 5.7% more clean fuel for cooking than non-migrants. Furthermore, as the remittances are endogenous, the instrumental variable approach was employed and average province rainfall times the log of distance to the nearest bank was used as the instrument. The results of the Control Function approach show that a 1% increase in migrant remittances increased clean cooking fuel use by 0.04 units. We also used Instrumental Variable (IV) mediation analysis to identify the mediating effect of household wealth on the relationship between remittances and cooking fuel choice. The results showed that household wealth significantly mediates this relationship.

Accordingly, Chapter 3 has a threefold contribution to the literature: (1) this was a pioneering study using household wealth as a mediating variable to examine the impact of migrant remittances on the type of cooking fuel used; (2) this was the first study to compare the use of clean fuel for cooking between migrant and non-migrant households, based on nationally representative data from over 78,000 households; and (3) this study isolated migrant remittances as a driver of household fuel choice, which has received less attention in earlier research.

In Chapter 4, we looked at the use of migrant remittances beyond cooking fuel and investigated how migrant remittances affect energy poverty in Sri Lanka. Only a few studies have been conducted to date to investigate this association (Agradi, 2023; Barkat et al., 2023; Hosan et al., 2023), and their insights about the mechanism through which remittances influence energy poverty are unclear. Despite this, most previous research shows that migrant remittances have a significant impact on income inequality, and income inequality has a substantial impact on energy poverty. Income inequality has been identified as the major impediment to energy poverty (Bardazzi, Bortolotti, & Pazienza, 2021; Igawa & Managi, 2022; Nguyen & Nasir, 2021) because most low-income households cannot afford the cost of clean energy, and they rely on solid fuels, which are detrimental to human health, educational quality, and overall social well-being (Awaworyi Churchill et al., 2020; Kose, 2019; Njiru & Letema, 2018). This will further reduce the income of low-income households and widen the income gap between low and high-income earners, resulting in high income inequality. Many studies have observed that energy poverty increases as income inequality rises (Acheampong, Shahbaz, Dzator, & Jiao, 2022; Bardazzi et al., 2021; Galvin, 2019; Galvin & Sunikka-Blank, 2018; Nguyen & Nasir, 2021). Simultaneously, numerous studies have found that migrant remittances reduce income inequality (Acosta, Calderón, Fajnzylber, & Lopez, 2008; Azizi, 2021; Bang, Mitra, & Wunnava, 2016). As a result, Chapter 4 integrated two distinct forms of literature: remittances and energy, through income inequality, and addressed four research questions: (1) do migrant remittances reduce energy poverty; (2) do migrant remittances reduce income inequality; (3) does income inequality increase energy poverty; and (4) is income inequality mediating the relationship between migrant remittances and energy poverty.

To answer the above research questions, this study used pseudo-panel data from 84,483 households after making necessary adjustments to the variables of interest in the study. As remittances are endogenous, an instrumental variable approach was used as the estimation technique and the instrument was average province rainfall times the log of distance to the nearest bank. The Multidimensional Energy Poverty Index (MEPI) was used to operationalize the dependent variable, energy poverty, and the Per Capita Gini Index was used to measure the mediating variable, income inequality. The Two-Stage Least Squares (2SLS) method was used to answer the first research question, and the results showed that remittances significantly reduced energy poverty. IV mediation analysis was used to answer the remaining research questions. According to the findings, migrant remittances reduce income inequality, while income inequality increases energy poverty. Notably, income inequality significantly mediated the relationship between remittances and energy poverty.

Chapter 4 has a three-fold contribution to the literature; (1) this was the first study examining the impact of migrant remittances on multidimensional energy poverty using pseudo-panel data from over 84,000 households; (2) this was a pioneering study using income inequality as a mediating variable to examine the impact of migrant remittances on energy poverty; and (3) this study used an advanced statistical technique, the instrumental variable approach for pseudo-panel data, to determine both the direct and mediating effects of the variables involved.

Finally, in Chapter 5, we determined the causes and economic implications of Sri Lanka's current energy crisis, its effect on energy poverty and the attainment of SDG 7. Four factors affected this crisis: (1) the government's tax cuts in 2019; (2) the complete transition to organic farming in 2021; (3) a dramatic drop in migrant remittances; and (4) a significant drop in tourism revenue. Adopting a floating exchange rate system and the Russia-Ukraine war in 2022 exacerbated the energy crisis with skyrocketing fuel prices, resulting in hyperinflation. A prolonged energy crisis has contributed to energy poverty and impeded the achievement of SDG 7. For example, the country experienced the longest power outage in the world, lasting 13 hours per day, and the government forced people to cook with fuelwood or other unclean fuel alternatives (The Guardian, 2022).

The immediate and effective solution to the current energy crisis is to boost migrant remittances because, on the one hand, they are critical pillars of Sri Lanka's foreign exchange reserves (CBSL, 2022a). On the other hand, migrant remittances enhance the consumption of clean cooking fuels and contribute to the reduction of energy poverty (Jayasinghe et al., 2021). According to the findings of Chapters 3 and 4, a decline in remittance income has a major impact on the level of cooking fuel consumption and energy poverty in Sri Lanka. For instance, the findings showed that a 1% increase in remittances increased clean fuel consumption by 0.037 units, and decreased energy poverty by 0.004. According to CBSL (2022a), migrant remittances fell by around 40% in 2022 compared to 2021 as a result of the current energy crisis. A 40% decline in remittance income would reduce clean fuel use by 0.16 units while increasing energy poverty by 0.0016 units. Therefore, the Sri Lankan government should take the necessary measures to stop the existing energy crisis and minimize energy poverty, to enable the country to achieve SDG 7 by 2030.

This thesis highlights the determinants of cooking fuel choice and synergy between SDGs 7, 6 and 4, the association between migrant remittances and cooking fuel choice through household wealth, and the relationship between migrant remittances and energy poverty through income inequality. The overall contribution and a summary of the study are presented in Chapter 6, which also discusses the main policy implications and limitations of the study and presents considerations for future research.

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Chapter 2: Clean Energy, Clean Water and Quality Education; Prospects of Achieving Sustainable Development Goals (SDGs) in Sri Lanka

2.1 Introduction

Energy services and access are vital contributors to economic, social, and human development (Alem et al., 2016; Guta, 2018). As a result, the United Nations has designated energy as the seventh Sustainable Development Goal (SDG 7), ensuring universal access to affordable, reliable, and modern energy by 2030. However, nearly 2.4 billion people worldwide still cook with solid fuels such as fuelwood, biomass, and crop residues (IEA, 2022). Furthermore, an estimated 2.3 billion people will continue to rely on such fuels by 2030, reflecting the sluggish progress of the energy transition (United Nations, 2020). The massive use of solid fuels for cooking has detrimental effects on human health and environmental sustainability.

The incomplete combustion of solid fuels directly causes substantial indoor air pollution (IAP) by producing carbon dioxide (CO_2), carbon monoxide (CO), particulate matter ($PM_{2.5}$), and other greenhouse gasses (Balakrishnan et al., 2018; Chattopadhyay et al., 2021; Muller & Yan, 2018; Shupler et al., 2018). IAP is potentially hundreds of times more harmful to human health than outdoor air pollution (Smith & Mehta, 2003). Moreover, it has been classified as the world's ninth-largest health risk, accounting for 3.2 million deaths (IEA, 2022). In addition, fuelwood extraction for cooking leads to deforestation, threatening other ecosystem services such as wildlife habitat, local temperature, and water filtration (Gebreegziabher et al., 2012; Heltberg, 2005). One of the best ways to reduce IAP is to use more clean cooking fuels such as electricity, Liquefied Petroleum Gas (LPG), and solar power, because they can reduce the considerable levels of IAP (Chattopadhyay et al., 2021; IEA, 2020). However, the energy transition from solid to clean is a long and challenging process for most developing countries, as it requires a higher level of financial, economic, and social development. Therefore, the energy transition process is attracting increased attention among scholars.

The process of energy transition was theoretically first addressed by the energy ladder hypothesis (Hosier & Dowd, 1987). It states that households first move from solid fuels to transitional fuels and then to cleaner fuels when the socioeconomic status of households increases, especially income. This theory assumes that households give up the used fuel entirely and move on to a new fuel, and it is a linear and unidirectional process (Heltberg, 2004; Leach, 1992). In line with the energy ladder hypothesis, most researchers found household income[1] as the most significant determinant of cooking fuel choice. In addition, household wealth[2], demographic characteristics of the head and spouse [3] (such as gender, marital status, and age), educational level of the head and spouse[4], household characteristics such as household size[5], number of children[6] and number of females[7], housing characteristics[8] (for example, the number of bedrooms, the type of wall, floor, and roof, the source of drinking water, and the type of toilets) play a vital role in selecting the fuel for cooking.

However, there is substantial heterogeneity between various empirical studies, as different studies use different variables, research approaches, study contexts, and analysis models. Thus, knowledge about the drivers of energy choice and the transition is still questionable. Due to this, there is no single framework to predict the household energy consumption structure (Frederiks et al., 2015). For example, some studies found that male-headed households are more likely to use clean fuels for cooking (Choumert-Nkolo et al., 2019; Dash et al., 2018). On the other hand, many studies found that female-headed families are more likely to choose clean fuels (Acharya & Adhikari, 2021; Behera et al., 2015; Mottaleb et al., 2017; Rahut et al., 2017; Waleed & Mirza, 2020). Further, several studies found gender plays no role in selecting cooking fuel (Abebaw et al., 2019; Liao et al., 2019; Narasimha Rao & Reddy, 2007; Ouedraogo, 2006). As a result, if SDG 7 is to be realized by 2030, a precise framework for identifying the determinants of energy choice is critical.

Furthermore, some of these determinants are directly linked to specific SDGs. For instance, the education of the heads and spouses relates to SDG 4 (quality education), and the drinking water and sanitation facilities relate to SDG 6 (clean water). SDG 4 has been identified as one of the SDGs with higher synergetic co-benefits than other SDGs (Pradhan et al., 2017). Moreover, Fader et al. (2018) found that SDG 6 enhances the achievement of SDG 7. This implies that although each SDG focuses on different aspects, most SDGs are integrated, indivisible, and create synergies. The synergy between two variables exists when their combined outcome is greater (positive synergy) or less than (trade-offs) the sum of their individual outcomes (Luukkanen et al., 2012; Mainali, Luukkanen, et al., 2018). However, SDG interactions have weak conceptual and scientific

[1] Amoah, 2019; Damette et al., 2018; Dash et al., 2018; Ravindra et al., 2019; Song et al., 2018
[2] Abbas et al., 2020; Mottaleb et al.,2017; Rahut et al., 2016; Song et al., 2018
[3] Behera et al., 2015; Choumert-Nkolo et al., 2019; Mensah & Adu, 2015; Mottaleb et al., 2017; Rahut et al., 2017; Waleed & Mirza, 2020
[4] Acharya & Adhikari, 2021; Acharya & Marhold, 2019; Amoah, 2019; Ravindra et al., 2019; Sharma et al., 2020; Waleed & Mirza, 2020
[5] Abbas et al., 2020; Paudel et al., 2018; Sharma et al., 2019; Sharma et al., 2020; Waleed & Mirza, 2020)
[6] Baiyegunhi & Hassan, 2014; Behera et al., 2015
[7] Behera et al., 2015; Dash et al., 2018; Waleed & Mirza, 2020
[8] Heltberg, 2005; Liao et al., 2019; Özcan et al., 2013.

underpinnings (ICSU, 2017). In addition, most of the studies conducted to find synergies are qualitative (Halsnæs & Garg, 2011; Weitz et al., 2018). Thus, it is difficult to provide any quantitative basis for evaluating synergies. Moreover, a lack of proper understanding of synergies leads to the creation of incoherent policies by delaying the outcomes of the SDG agenda (Mainali, Luukkanen, et al., 2018). Therefore, there is a clear need for approaches and tools to identify the inter-relationships of SDGs in promoting the SDG agenda more efficiently (Weitz et al., 2018).

Thus, a comprehensive understanding of the synergy between SDGs and the determinants of cooking fuel choice is needed to implement coherent cross-sectional policies to achieve SDG 7. Accordingly, the objective of this study is to investigate the factors that influence cooking fuel choice and the synergies between SDGs 4, 6, and 7. As a result, this study attempts to answer three research questions: (1) what factors influence the cooking fuel choice; (2) does synergy exist between SDG 4 and SDG 7; and (3) does synergy exist between SDG 6 and SDG 7. For research on this topic, we selected Sri Lanka for three reasons. First, the United Nations (2020) has rated SDG 7 as a stagnating goal for Sri Lanka as about 69% of the population has no access to clean fuels and technologies. Second, energy poverty is prevalent in Sri Lankan families, with the most pressing issue being a lack of modern cooking fuel (Jayasinghe et al., 2021). Third, there has been very little research on cooking fuel use at the household level in Sri Lanka, and also none of the studies has used an econometrics specification model (Nandasena et al., 2012; Rajmohan & Weerahewa, 2010; Wickramasinghe, 2011).

Accordingly, our contribution to literature is twofold. First, this will be the pioneering study to explore the synergies between SDG 4, 6, and 7 using nationally representative data. A thorough understanding of SDGs' linkages will help to integrate different sector-specific programs and develop consistent cross-sectoral policies. Second, this study adds to the literature by investigating the driving forces of cooking fuel choice, covering about 79,000 households. The results can help to prepare effective government policies for the energy transition at the household level.

The remainder of this paper is organized as follows: Section 2 reviews the data and variable descriptions. Section 3 outlines the empirical model, and Section 4 describes the results and discussion. Finally, section 5 concludes the paper and discusses the policy implications.

2.2 Data and Variable Description

2.2.1 Data Description

This study employs cross-sectional repeated data from four waves of the Household Income and Expenditure Surveys (HIES) for the years 2009, 2012, 2016, and 2019. The Department of Census and Statistics in Sri Lanka conducts HIES every three years and collects demographics, income, expenditure, school education, health, and household asset data through a direct survey questionnaire. The survey's sample design is two-stage stratified. At the primary point, a sample of 2500 primary sampling units was selected from the sampling frame for the survey, and ten housing units were then chosen for the survey from each primary sampling unit. The total sample sizes were 23641, 25319, 25640 and 24922 housing units, in 2009, 2012, 2016 and 2019, respectively. However, only 19 958, 20 540, 21 756, and 19 911 households replied each year, for a total of 81365 households, and we ended up with 79106 households after removing the rows with missing values for variables relevant to the study.

2.2.2 Variable Description

The dependent variable of the study is cooking fuel consumption. The cooking fuel mix in Sri Lanka comprises fuelwood, kerosene, LPG and electricity. We divide cooking fuel into three categories based on the energy ladder hypothesis: (1) solid fuel (fuelwood, saw/paddy husk, and other); (2) transitional fuels (kerosene); and (3) clean fuels (LPG and electricity). The distribution of households by primary cooking fuel use is presented in Figure. 2.1.

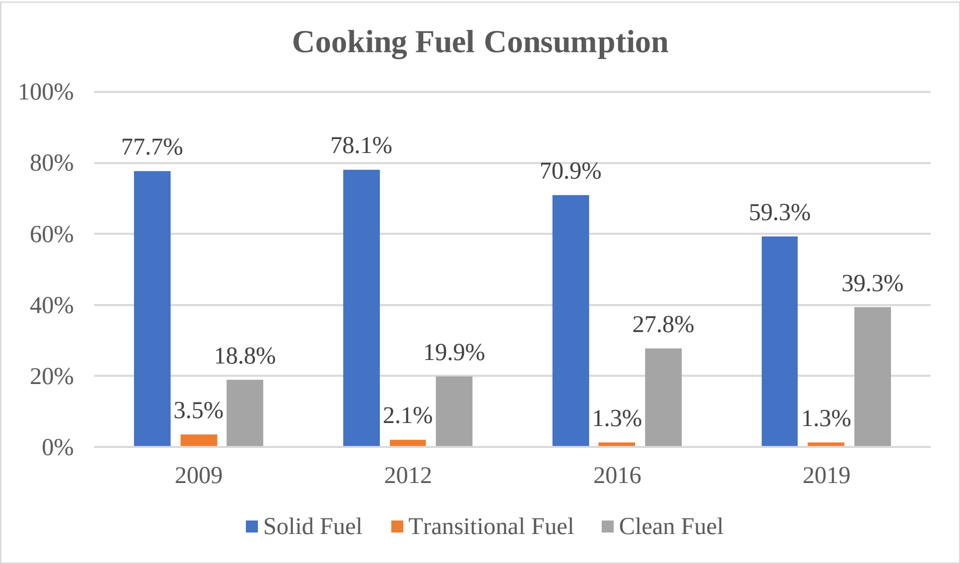

Figure. 2.1. Cooking Fuel Consumption

Figuer 2.1 shows that solid fuels dominate as the primary cooking fuel, but the proportion of households using those decreases from 77.7% in 2009 to 59.3% in 2019. In addition, there has been a gradual decrease in the proportion of households using transitional fuels; however, the proportion of households with clean fuels considerably increased (18.8%, 19.9%, 27.8%, and 39.3% for 2009, 2012, 2016 and 2019, respectively).

The independent variables of the study include household[9] income, household wealth, age, gender, education, marital status, employment sector of household head[10], age, and education of spouse, number of children under five, number of females, household size[11], water and sanitation facilities, number of bedrooms, type of wall, floor, and roof, and residential sector[12]. Table 2.1 depicts the descriptive statistics of the variables interested.

Table 2.1: Descriptive Statistics

	2009		**2012**		**2016**		**2019**		**Overall**	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Household Income	104500	157865	113904	414574	181265	463301	174387	874902	144081	944,521
Wealth Qui.	3.00	1.41	2.99	1.42	3.02	1.41	3.00	1.42	3.00	1.41
Head Age	50.74	13.99	50.95	13.95	52.57	14.02	54.22	14.03	52.13	14.07
Head Edu.	8.71	4.13	8.82	3.98	8.93	3.87	9.09	3.76	8.87	3.94
Spouse Age	31.96	22.78	32.37	23.12	32.88	24.17	37.59	23.13	33.69	23.43
Spouse Edu.	6.60	5.33	6.77	5.36	6.64	5.32	7.48	5.04	6.87	5.28
Household Size	4.31	1.77	4.15	1.72	4.09	1.65	4.02	1.63	4.15	1.70
No. Children	0.25	0.51	0.23	0.56	0.23	0.51	0.18	0.45	0.23	0.51
No. Females	2.21	1.19	2.16	1.18	2.12	1.15	2.05	1.08	2.14	1.15
No. Bedrooms	2.26	1.11	2.31	1.09	2.39	1.09	2.44	1.05	2.35	1.08
	Pro.	**SD**	**Pro.**	**SD**	**Pro.**	**SD**	**Pro.**	**SD**	**Pro.**	**SD**
Cooking Fuel										
Solid	0.777	0.003	0.781	0.003	0.709	0.003	0.593	0.003	0.715	0.002
Trans.	0.034	0.001	0.021	0.001	0.013	0.001	0.013	0.001	0.020	0.001
Clean	0.188	0.003	0.199	0.003	0.278	0.003	0.393	0.003	0.265	0.002
Head Gender										
Male	0.759	0.003	0.763	0.003	0.741	0.003	0.749	0.003	0.752	0.002
Female	0.241	0.003	0.237	0.003	0.259	0.003	0.254	0.003	0.248	0.002
Head Marital Status										
Married	0.785	0.003	0.789	0.003	0.777	0.003	0.770	0.003	0.780	0.002
Unmarried	0.215	0.003	0.211	0.003	0.223	0.003	0.230	0.003	0.220	0.002
Head Employ. Sector										
Govern.	0.421	0.004	0.425	0.004	0.393	0.003	0.381	0.003	0.405	0.002
Private	0.279	0.003	0.282	0.003	0.310	0.003	0.295	0.003	0.292	0.002
Other	0.300	0.003	0.293	0.003	0.297	0.003	0.324	0.003	0.303	0.002
Drinking Water										
Safe	0.967	0.001	0.889	0.002	0.890	0.002	0.935	0.002	0.919	0.001
Unsafe	0.033	0.001	0.111	0.002	0.110	0.002	0.065	0.002	0.081	0.001

[9] A household is defined as a group people who live together and have a common arrangement for cooking.

[10] The head of the household is a person who usually resides in the household and is acknowledged by the other members of the household as the head of the household.

[11] Household size refers to the number of persons usually living in the household, including boarders and servants.

[12] The rural sector includes all the areas other than the areas governed by Municipal Councils (MCs) and Urban Councils (UCs) and the estate sector.

Toilet Use										
Indoor	0.456	0.001	0.456	0.004	0.453	0.003	0.437	0.003	0.704	0.002
Outdoor	0.530	0.001	0.532	0.004	0.543	0.003	0.539	0.003	0.262	0.002
No toilet	0.014	0.001	0.012	0.001	0.005	0.001	0.024	0.003	0.004	0.001
Toilet Type										
Improved	0.940	0.002	0.973	0.001	0.979	0.001	0.973	0.001	0.967	0.001
Unimproved	0.060	0.002	0.027	0.001	0.021	0.001	0.027	0.001	0.033	0.001
Wall Type										
Permanent	0.918	0.002	0.928	0.002	0.954	0.001	0.950	0.002	0.938	0.002
Semi-Per.	0.082	0.002	0.072	0.002	0.046	0.001	0.049	0.002	0.062	0.002
Floor Type										
Permanent	0.975	0.001	0.931	0.002	0.956	0.001	0.922	0.002	0.946	0.001
Semi-Per.	0.025	0.001	0.069	0.002	0.044	0.001	0.078	0.002	0.054	0.001
Roof Type										
Permanent	0.977	0.001	0.872	0.002	0.917	0.002	0.941	0.002	0.926	0.001
Semi-Per.	0.022	0.001	0.128	0.002	0.083	0.002	0.059	0.002	0.074	0.001
Sector										
Urban	0.263	0.003	0.250	0.003	0.263	0.003	0.161	0.003	0.209	0.001
Rural	0.649	0.003	0.661	0.003	0.649	0.002	0.796	0.003	0.726	0.001
Estate	0.088	0.002	0.089	0.002	0.088	0.001	0.043	0.001	0.065	0.001
Observations	19157		19848		20640		19461		79106	

Accordingly, the average household income is SLRs.144081 (US$ 424, converted to US$1 = SL Rs.340) and it is increasing within the decade. The average wealth quintile is 3, indicating that most families are middle-income. The majority of heads are males and around 78% are married. On average, the head has a grade 9 education, while the spouse has a grade 7 education. Most household heads are working in the government sector. The average household has four members, and two of them are women. 91.9% of families have safe drinking water, while 96.7% have improved toilets. More than 90% of dwellings have permanent walls, roofs, and floors. 72.6% of the families are located in rural areas, 20.9% of the families are located in urban areas, and only 6.5% of households are living in the estate sector.

2.3 Empirical Strategy and Econometric Models

The first objective of this study is to identify the determinants of cooking fuel consumption. As cooking fuel consumption has three nominal, unordered alternatives (solid, transitional, and clean fuels), we employ a multinomial logit model (Baiyegunhi & Hassan, 2014; Dash et al., 2018; Ouedraogo, 2006; Rahut et al., 2017; Song et al., 2018). The second objective is to identify the synergies between SDG 4, 6, and 7, and for that, we use Advanced Sustainability Analysis (Luukkanen et al., 2012; Mainali, Ahmed, et al., 2018). Furthermore, we use Principal Component Analysis to construct the household wealth index (Chasekwa et al., 2018; Filmer & Pritchett, 2001; Vyas & Kumaranayake, 2006).

2.3.1Multinomial Logit Model (MNL)

The MNL model's theoretical framework is based on random utility theory. This theory states that every individual is a rational decision-maker and selects the best among alternatives to maximize utility (McFadden, 1978). As a result, a household chooses the primary cooking fuel that provides the most utility from various energy sources (Mensah & Adu, 2015). Accordingly, the indirect utility of a cooking fuel choice j (j=1,2,3) in the time period t (t = 1,2,3) for i^{th} observation of each household with a random effect can be described as follows:

$$V_{ijt} = X_{it}\beta_j + u_i + \varepsilon_{ijt} \tag{2.1}$$

where X_{it} is a vector of explanatory variables for each household's cooking fuel preference, β_j is a vector of cooking fuel choice-specific coefficients, u_i is an unobserved heterogeneity of household characteristics, and ε_{ijt} is an independently and identically distributed random error term. Thus, the conditional probability that household i chooses cooking fuel j in time t with unobserved household heterogeneity is provided by equation (1.2).

$$\Pr\left(f_{it} = t_j | x_{it}, u_i\right) = \frac{\exp\left(x_{it}\beta_j + u_i\right)}{1 + \sum_{k \neq B}\left(x_{it}\beta_k + u_i\right)}, j \neq B \tag{2.2}$$

where B denotes the base outcome of the cooking fuel type. The equation shows that the probability of choosing a cooking fuel type is conditional on the set of household-level effects and the observable household characteristics (Choumert-Nkolo et al., 2019).

The assumption of the Independence of Irrelevant Alternatives (IIA) is the key downside of the standard multinomial logit model. IIA ignores individual heterogeneity and assumes that household decisions are made independently, both within and across alternatives. Panel data is more likely to have this unobserved heterogeneity since it contains numerous observations for the same individual across time (Zhu et al., 2010). Thus, incorporating random errors into the model relaxes the IIA property (Glick & Sahn, 2005; Grilli & Rampichini, 2007). Furthermore, random effect estimates are considered more robust and efficient since they capture the unobserved household impact. Therefore, we adopt random effects panel multinomial logit regression to examine the determinants of household energy choice for cooking (Alem et al., 2016; Choumert-Nkolo et al., 2019).

2.3.2 Advanced Sustainability Analysis (ASA)

This study uses an ASA approach to identify the synergies between SDGs 4, 6, and 7. This approach has been used in quantitative evaluations of synergies in several studies (Luukkanen & Kaivo-oja, 2002; Luukkanen et al., 2012; Mainali, Luukkanen, et al., 2018; Vehmas et al., 2007). The ASA approach was developed under the European framework program, and it helps in analysing complex sustainable development questions in an integrated manner. Furthermore, it offers decision-makers a tool for different dimensions of sustainable development for policy analyses and policy formulations (Luukkanen et al., 2012). Figure 2.2 illustrates the generic evaluation framework for sustainable development based on the ASA approach.

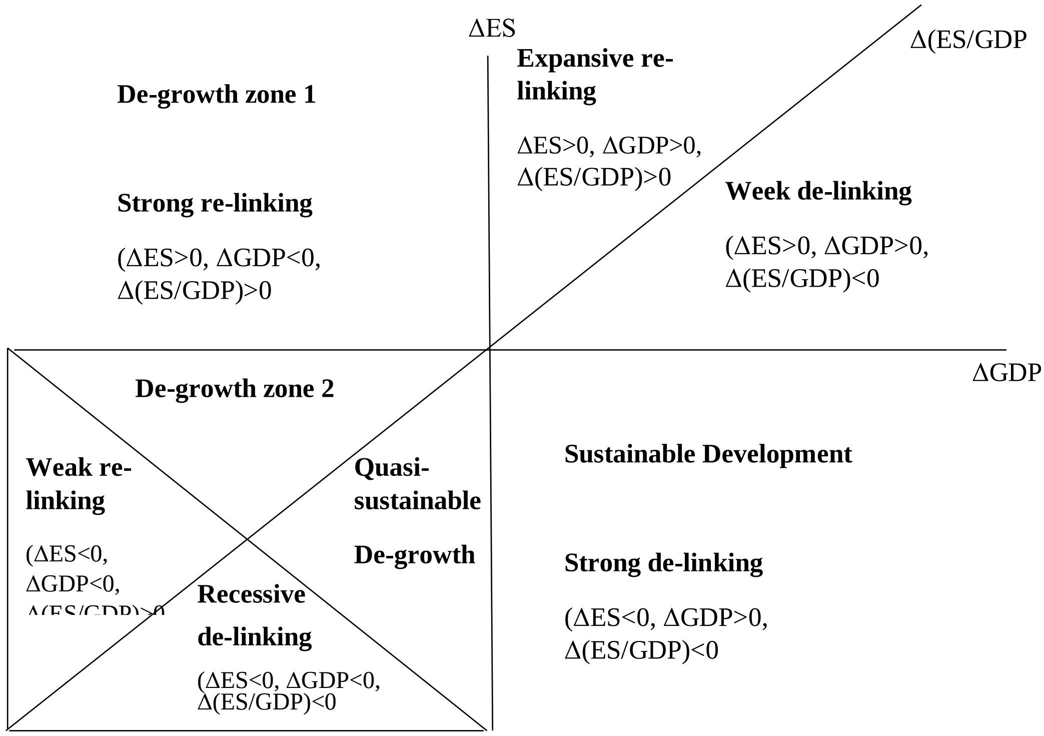

Figure 2.2: Framework of Evaluating Sustainable Development (Kaivo-oja et al., 2014; Mainali, Luukkanen, et al., 2018; Vehmas et al., 2007)

The framework describes the various facets of sustainable development in terms of economic growth (GDP), environmental stress (ES), and the environmental intensity of economic growth (ES/GDP). It highlighted two situations: (1) re-linking and (2) de-linking. Re-linking indicates that ES increases as GDP rises over time, suggesting synergies between the two variables, while de-linking states that ES falls as GDP rises, meaning a trade-off between the two variables. The re-linking and de-linking principles of the ASA approach can assist researchers in identifying positive synergies and trade-offs among variables in a variety of study contexts.

Synergy is statistical interaction among two independent variables, say Y_i and Y_j, and conventionally such interactions are presented as the product of those variables, i.e., $Y_i \times Y_j$ (Luukkanen et al., 2012; Southwood, 1978). A positive synergy between two variables exists when their combined effect is greater than the sum of individual effects. Mathematically, this can be expressed as:

$$Z = Ax + By + Cxy + D \tag{2.3}$$

where Z is the dependent variable, x and y are independent variables, and A, B, C, and D are coefficients. The component of "Cxy" determines the synergy between variables x and y. If we observe the change in these variables (x and y) between two points, say P (x_0,y_0) to Q (x_1,y_1), we can determine the change in the area (Δz) as:

$$\Delta z = A\Delta x + B\Delta y + C\Delta x\Delta y \tag{2.4}$$

The synergy of the inputs is determined by the third component, i.e., ΔxΔy, which is represented by the shaded area in Fig. 2.3 (a) and (b). The synergy can be either positive or negative. If the change in y is positive for the positive changes in x, then ΔxΔy is positive, indicating synergy. On the contrary, if the change in y is negative to the positive changes in x, then ΔxΔy is negative, indicating a trade-off situation. The potential synergy can be expressed as the slope of the line AB, i.e., the ratio of Δy/Δx (Luukkanen et al., 2012).

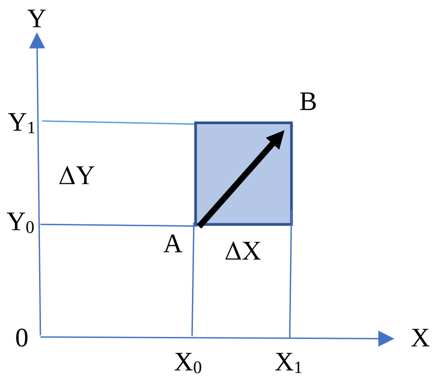

Figure. 2.3(a): Synergy

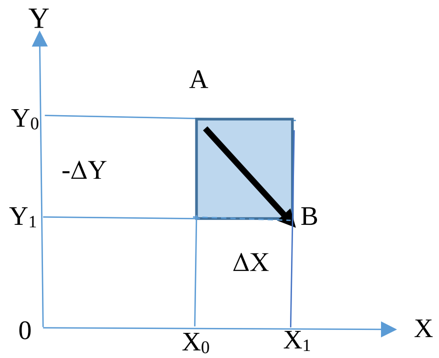

Figure. 2.3(b): Trade-off

Maximum synergy can be obtained when relative changes are equal (Δx = Δy = 1). Therefore, potential synergy/trade-off between two variables can be measured between -1 and +1. The positive sign indicates the synergy, while the negative sign indicates a trade-off between two variables.

2.4 Results & Discussion

2.4.1 MNL Results

The random-effects panel multinomial logit regression is used to investigate the determinants of cooking fuel consumption (see Table 2.2). For comparison purposes, Appendix 2A displays the effects of full regression analysis with pooled MNL and a fixed effect MNL. All fuel alternatives are compared to solid fuels, which served as the base category.

Table 2.2: Random Effects MNL Results

Explanatory Variables	Coefficients		Marginal Effect		
	Trans. Fuels	Clean Fuels	Solid Fuels	Trans. Fuels	Clean Fuels
Household Income (log)	0.008	0.224***	-0.033***	-0.000**	0.033***
	(0.016)	(0.011)	(0.002)	(0.000)	(0.002)
Household Wealth					
Poor Households	0.501***	1.102***	-0.165***	0.004***	0.162***
(Poorest = 0)	(0.084)	(0.052)	(0.007)	(0.001)	(0.007)
Medium Wealth Households	0.957***	1.786***	-0.269***	0.008***	0.262***
(Poorest = 0)	(0.090)	(0.051)	(0.007)	(0.001)	(0.007)
Wealthy Households	0.998***	2.415***	-0.361***	0.007***	0.354***
(Poorest = 0)	(0.102)	(0.052)	(0.007)	(0.001)	(0.007)
Wealthiest Households	1.143***	3.315***	-0.494***	0.006***	0.487***
(Poorest = 0)	(0.130)	(0.056)	(0.008)	(0.002)	(0.008)
Household Head					
Gender (Female = 0)	0.046	-0.044	0.006	0.001	-0.007
	(0.085)	(0.037)	(0.006)	(0.001)	(0.005)
Marital Status (No = 0)	-0.526***	-0.305***	0.050***	-0.006***	-0.044***
	(0.135)	(0.052)	(0.008)	(0.002)	(0.008)
Age (log Squared)	-0.102***	-0.025***	0.005***	-0.001***	-0.003***
	(0.017)	(0.007)	(0.001)	(0.001)	(0.001)
Primary Education	-0.011	0.025	-0.004	-0.000	0.004
(No Schooling = 0)	(0.134)	(0.077)	(0.011)	(0.002)	(0.011)
Secondary Education	0.002	0.599***	-0.087***	-0.001	0.089***
(No Schooling = 0)	(0.138)	(0.077)	(0.011)	(0.002)	(0.011)
Tertiary Education	-0.213	1.178***	-0.169***	-0.005	0.174***
(No Schooling = 0)	(0.333)	(0.097)	(0.015)	(0.004)	(0.014)
Government Employee	-0.189**	-0.159***	0.025***	-0.002**	-0.023***
(Other Sector = 0)	(0.075)	(0.030)	(0.005)	(0.001)	(0.004)
Private Sector Employee	-0.339***	-0.460***	0.070***	-0.003***	-0.067***
(Other Sector = 0)	(0.081)	(0.029)	(0.004)	(0.001)	(0.004)
Spouse					
Age (log Squared)	-0.029***	0.002	-0.001	0.000***	0.000
	(0.009)	(0.004)	(0.001)	(0.000)	(0.001)

Primary Education	0.309*	0.027	-0.007	0.004*	0.003
(No Schooling = 0)	(0.183)	(0.096)	(0.014)	(0.002)	(0.014)
Secondary Education	0.037	0.306***	-0.045***	0.000	0.045***
(No Schooling = 0)	(0.184)	(0.094)	(0.014)	(0.002)	(0.014)
Tertiary Education	-0.586	0.857***	-0.119***	-0.009	0.128***
(No Schooling = 0)	(0.464)	(0.115)	(0.018)	(0.005)	(0.017)
Household Characteristics					
Household Size	0.030	-0.143***	0.021***	0.001	-0.021***
	(0.023)	(0.010)	(0.001)	(0.000)	(0.001)
Number of Children Under 5	-0.002	0.185***	-0.027***	-0.000	0.027***
	(0.061)	(0.023)	(0.004)	(0.001)	(0.003)
Number of Females	-0.093***	-0.001	0.001	-0.001***	0.000
	(0.035)	(0.014)	(0.002)	(0.000)	(0.002)
Housing Characteristics					
Number of Bedrooms	-0.784***	-0.311***	0.053***	-0.009***	-0.044***
	(0.040)	(0.012)	(0.002)	(0.000)	(0.002)
Safe Drinking Water	0.311**	0.123***	-0.021***	0.003**	0.299***
(Unsafe Water = 0)	(0.134)	(0.045)	(0.007)	(0.009)	(0.106)
Indoor Toilets	1.325**	2.040***	-0.310***	0.011	0.085***
(No Toilets = 0)	(0.739)	(0.724)	(0.105)	(0.017)	(0.011)
Outdoor Toilets	1.114	1.171	-0.181*	-0.011	0.171
(No Toilets = 0)	(0.738)	(0.724)	(0.106)	(0.009)	(0.107)
Improved Toilets	-0.156	0.133*	-0.017*	-0.002	0.020**
(Unimproved Toilets=0)	(0.126)	(0.069)	(0.010)	(0.002)	(0.010)
Permanent Wall	0.012	0.482***	-0.070***	-0.001	0.071***
(Semi-Permanent = 0)	(0.100)	(0.069)	(0.010)	(0.001)	(0.010)
Permanent Floor	0.482***	0.181***	-0.031***	0.005***	0.026***
(Semi-Permanent = 0)	(0.152)	(0.050)	(0.008)	(0.002)	(0.007)
Permanent Roof	-0.087	-0.462***	0.068***	-0.000	-0.068***
(Semi-Permanent = 0)	(0.114)	(0.062)	(0.010)	(0.001)	(0.009)
Residential sector					
Urban (Estate[13] = 0)	3.233***	1.841***	-0.300***	0.035***	0.265***
	(0.176)	(0.066)	(0.009)	(0.002)	(0.009)
Rural (Estate = 0)	0.846***	0.261***	-0.046***	0.009***	0.037***
	(0.180)	(0.065)	(0.010)	(0.002)	(0.010)
Year and District Dummies	Yes				
Number of Observations	79,106				

Notes: Huber – White cluster-robust sandwich standard errors in parentheses; ***,**, and * represent significance at the 1%, 5% and 10% levels, respectively. Dummy Variables; Household Wealth, Gender, Marital Status, Education, Employment Sector, Drinking Water Source, Toilet use and type, Type of wall, floor and roof, and residential Sector.

[13] Estate sector consists of all plantations which are 20 acres or more in extent and ten or more resident labourers Census and Statistics Department. (2012). *Census and Statistics Survey* (978 – 955 – 577 – 940 – 1). http://203.94.94.89/mainsite/Population/StaticalInformation/CPH2011/CensusPopulationHousing2012-FinalReport

As shown in Table 2.2, the estimated coefficient for household income is positive and statistically significant for clean fuels, indicating that an increase in household income is more likely to increase the choice of clean fuels compared to solid fuels. This finding is consistent with the energy ladder hypothesis (Heltberg, 2004; Hosier & Dowd, 1987) and the findings of the literature (Baiyegunhi & Hassan, 2014; Behera et al., 2015; Damette et al., 2018; Mensah & Adu, 2015; Özcan et al., 2013; Ravindra et al., 2019; Sharma et al., 2019). This outcome is primarily motivated by the affordability of modern fuels against less costly traditional fuels (Mensah & Adu, 2015).

The predicted coefficient for the wealth indices positively, significantly, and progressively affects the choice of clean and transitional energy. In contrast, it has a negative, significant, and progressive impact on the choice of solid fuels. The results are consistent with the previous studies (Abbas et al., 2020; Baiyegunhi & Hassan, 2014; Behera et al., 2015; Mottaleb et al., 2017; Paudel et al., 2018; Rahut et al., 2017). This could be because wealthier households can afford the higher cost of modern fuels over solid fuels. Also, members of affluent families have better access to education, so they are more aware of the negative health effects of solid fuel consumption, and as a result, they use more clean for cooking than less-affluent families. Furthermore, wealth is a stock variable, and therefore, it increases the ownership of long-term assets such as modern housing facilities and durable goods. As a result, they shift to modern fuels as they are no longer interested in using solid energy (Mottaleb et al., 2017).

The results show the age of the head is negative and statistically significant for the probability of selecting clean fuels, reflecting that a rise in the age of the head is less likely to influence the preference towards clean energy. The results are consistent with the previous findings (Choumert-Nkolo et al., 2019; Liao et al., 2019; Mensah & Adu, 2015; Paudel et al., 2018). This may be because most older adults may have become used to conventional fuels and are less likely to move towards modern energy sources (Mensah & Adu, 2015). Moreover, Heltberg (2005) mentions that households will continue to use dirty energy like fuelwood through established loyalty, taste preferences, and traditional cooking methods. For example, most elders in Sri Lanka believe that food tastes better when cooked with fuelwood. Nonetheless, the findings of some studies contradict the findings of this study, which found a positive association between head age and clean fuel use (Behera et al., 2015; Özcan et al., 2013; Rahut et al., 2017; Sharma et al., 2020), and which found no relationship between head age and clean fuel use (Israel, 2002; Mottaleb et al., 2017). Moreover, if the head is married, there is a negative and significant coefficient for the clean fuel choice. Marriage increases the likelihood of having more members in the household, and as a result, households may choose more solid fuels to maintain a low monetary burden (Sharma et al., 2019).

Education has been identified as one of the main determinants of clean cooking fuel choice (Abbas et al., 2020; Acharya & Adhikari, 2021; Choumert-Nkolo et al., 2019; Hou et al., 2017; Mottaleb et al., 2017; Paudel et al., 2018; Ravindra et al., 2019; Waleed & Mirza, 2020). By confirming these studies, our findings also show that having secondary and tertiary education levels for the head and spouse are positive and statistically significant for clean fuel compared to solid fuels. A higher level of education can increase the clean fuel choice in two ways: (1) growing levels of education can raise awareness of the negative impacts of using solid fuel for cooking on human health and the environment (Sharma et al., 2019); and (2) higher levels of female education can raise the opportunity cost of collecting fuelwood, causing them to seek out more income-generating jobs (Farsi et al., 2007; Ravindra et al., 2019). Furthermore, the MNL estimates show that the employment sector of the head significantly influences cooking fuel choice. If the head is employed in the government or private sector (compared to the other sectors), the household is likely to increase the likelihood of choosing clean and transitional fuels. This could be due to the country's unique conditions, as they receive a fixed and consistent monthly income to spend on modern fuels.

Household size is negatively and statistically significant for clean fuels at a 1% level. This implies that an increase in the number of family members in the household reduces the use of clean fuels. The results are consistent with the findings of Sharma et al. (2019), Paudel et al. (2018), and Sharma et al. (2020). According to Sharma et al. (2019), large families have a high demand for cooking fuel, and therefore, to maintain a low monetary burden, households may choose more home-produced or collected solid fuels. Also, Mottaleb et al. (2017) highlighted that having more family members may have more unpaid labour to collect biomass, and the opportunity cost of collecting biomass is low. As a result, having a larger family size discourages clean cooking fuel (Acharya & Adhikari, 2021; Waleed & Mirza, 2020). However, this observation contradicts the findings of some studies (Baiyegunhi & Hassan, 2014; Choumert-Nkolo et al., 2019; Mensah & Adu, 2015; Ouedraogo, 2006). Furthermore, Amoah (2019) found no impact of household size in selecting cooking fuel.

The estimated coefficient for the number of children under 5 is positively and significantly related to the household choice of clean fuels. The marginal effect interprets that adding one child under five to the family is more likely to increase the clean fuel choice by 2.7%. Noticeably, the results are opposed to the findings of Behera et al. (2015) and Baiyegunhi and Hassan (2014). They highlight that having more children means having more child labour to collect fuelwood, increasing solid fuel consumption.

We found housing characteristics also have a considerable impact on cooking fuel choice. At a 1% level, the estimated coefficient for the number of bedrooms has a statistically significant and negative association with both clean and transitional fuel. In Mozambique Arthur et al. (2010) found households with more bedrooms adopt the more clean fuels. But, our result is inconsistent with Heltberg (2005) study, which found the number of bedrooms positively affects clean fuel demand for cooking. But, Özcan et al. (2013) did not find any impact. Having permanent walls and floors generates a significant positive effect on clean fuels. Surprisingly, an increase in the permanent roof leads to a decrease in clean fuel use. This would happen because houses with permanent roofs, such as asbestos, concrete, or metal sheets, build a smoke-hood or chimney in the roof to allow smoke from the hearth to escape when people cook inside using fuelwood. In addition, a dwelling with a permanent roof has less risk of using fire for cooking than a semi-permanent roof like Cadjan or straw. Therefore, there is a high probability of using more solid fuel for cooking. Yet, Liao et al. (2019) could not find any significant impact of housing conditions on cooking fuel choice. For drinking water and sanitation facilities, the estimated coefficient for safe drinking water improved toilets and having indoor toilets are positive and statistically significant for the probability of household choice of clean fuels at a 1% level. This is consistent with the Liao et al. (2019) study, which found families that use in-house tap water are more likely to use gas instead of firewood. Urban and rural households are more likely to use clean and transitional fuels than the estate sector.

The marginal effects highlight that it is more likely to use clean fuels in the urban sector than in the rural sector. Choumert-Nkolo et al. (2019), Paudel et al. (2018), Mensah and Adu (2015), and Sharma et al. (2019) also found that urban sector families use more gas and electricity than fuelwood as the primary cooking fuel. The possible explanations would be the difference in accessibility, reliability in supply, and the nature of buildings (Mensah & Adu, 2015). This indicates that supply-side factors are also critical drivers in the transition from traditional to modern energy.

2.4.2 Identification of Synergies: SDG 4; SDG 6; and SDG 7

Although each SDG focuses on different aspects, most SDGs are integrated and indivisible. Thus, gaining a greater understanding of these relationships will assist governments in prioritizing highly influential goals and improving cross-sectoral coordination. This segment, therefore, describes synergies between SDG 4, 6, and 7 using the ASA approach (Luukkanen & Kaivo-oja, 2002; Luukkanen et al., 2012; Mainali, Luukkanen, et al., 2018; Vehmas et al., 2007). Table 2.3 shows the targets and measurement variables for each SDG selected.

Table 2.3: SDG Targets and Measuring Variables

SDGs	Targets	Measuring/Tracking Indicators
SDG 4	**4.1** Ensure that all girls and boys complete free, equitable and quality primary and secondary education	The highest education level of the head and spouse
SDG 6	**6.1** Achieve universal and equitable access to safe and affordable drinking water for all	1.Main source of drinking water (Safe/Unsafe) 2.Water ownership 3.Sufficiency of water for drinking
	6.2 Achieve access to adequate and equitable sanitation and hygiene for all	1.Type of toilet facility (Improved/Unimproved) 2. Sharing of the toilet facility with other households (Shared/Unshared/no toilet) 3. Sufficiency of water for cooking & washing
SDG 7.1	**7.1** Ensure universal access to affordable, reliable, and modern energy services	Type of main cooking fuel

2.4.2.1 Synergy between SDG 4 and SDG 7

This section identifies the synergy between SDG 4 and SDG 7. SDG 4 ensures universal access to equitable and high-quality education for all by 2030. We used the mean of the highest level of education of both the household head and spouse and constructed an education index to measure SDG 4. SDG 7 ensures universal access to clean energy by 2030, and we used the proportion of households using clean cooking fuels (electricity and LPG) to measure SDG 7.

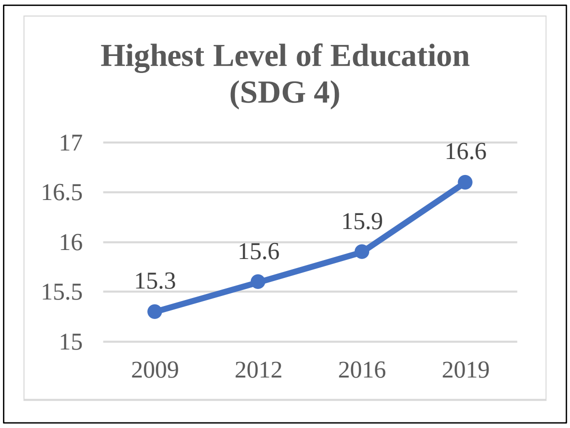

Figure 2.4(a): Highest Level of Education

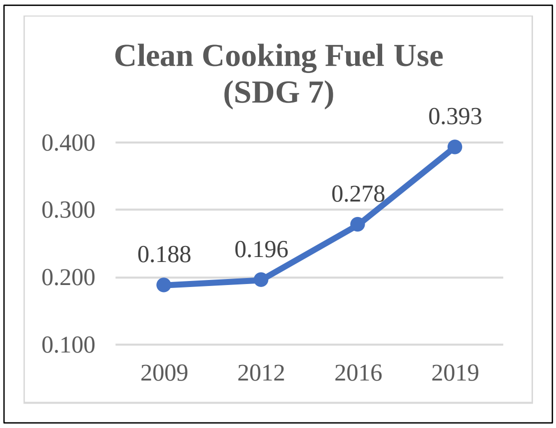

Figure 2.4(b): Clean Cooking Fuel Use

As shown in Figure 2.4 (a), the education index; the average education of household heads and spouses rose substantially from 2009 to 2019. The average education level was 15.3, 15.6, 15.9 and 16.6 years in 2009, 2012, 2016, and 2019, respectively. Following the same pattern, Figure 2.4 (b) depicts the gradual increase in modern cooking fuels. In 2009, the proportion of households using clean, modern cooking fuels was 18.8%, and the proportion had increased to 19.9%, 27.7% and 39.3% by 2009, 2012 and 2019, respectively.

Accordingly, both the education index and the use of clean cooking fuel have increased over time (See Figure 2.5). Following the principles of the ASA approach (more details are given in section 2.3.2), we identify expansive re-linking between education and clean cooking fuel because the change in education index (ΔEdu) is positive, change in clean fuel use (ΔCE) is positive, and and the marginal effect of two variables is positive (ΔCE/ΔEdu = 0.158). This demonstrates a strong synergy between SDGs 4 and 7, and the shaded area in the figure depicts re-linking or synergy between two SDGs according to the framework for evaluating sustainable development.

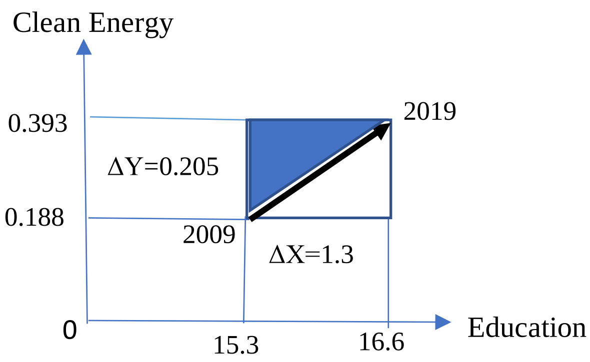

Figure 2.5 – Synergy between Clean Energy and Education

The results are consistent with the findings of Pradhan et al. (2017). This is possible because when both the head and spouse have a higher level of education, they are aware of the negative effects of solid fuel cooking on human health and environmental sustainability. As a result, they reduce the consumption of solid fuels as their opportunity cost is higher (Sharma et al., 2019). On the other hand, if both have a better education, they can both work in higher-paying jobs, increasing the household income. Then increase in income will encourage the use of more clean fuels for cooking as their affordability rises (Baiyegunhi & Hassan, 2014).

As a result, education can be used as a long-term policy to shift household fuel use from traditional to cleaner cooking fuels (Chambwera & Folmer, 2007). Sri Lanka has already met SDG 4 with a net primary school enrolment rate of 99.1% (United Nations, 2020) and a literacy rate (people aged 15 to 24) of 98.8% (Sachs et al., 2021). However, SDG 7 remains a major challenge because only 26.3% of people have access to clean fuels and cooking technologies. They also claim that the score is stagnating or growing at less than half the expected rate, implying that SDG 7 will not be met by 2030. As a result, policymakers can develop educational campaigns and school curricula about the private and social costs of solid fuel use, such as the health and environmental risks associated with IAP (Jaime et al., 2020). For instance, designing and implementing an educational programme aimed at secondary school students on clean energy access for cooking as a part of their curriculum.

4.2.2.2 Synergy between SDG 6 and SDG 7

SDG 6 strives to provide universal and equitable access to safe drinking water, sanitation, and hygiene facilities to all by 2030. To operationalize SDG 6, we created an additive index using the variables safe drinking water, water ownership, water sufficiency for drinking, improved toilets, indoor toilets, and water sufficiency for washing and bathing.

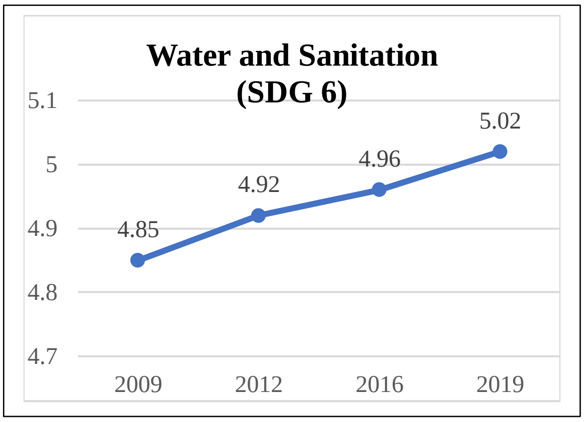

Figure 2.6(a): Water and Sanitation Facilities

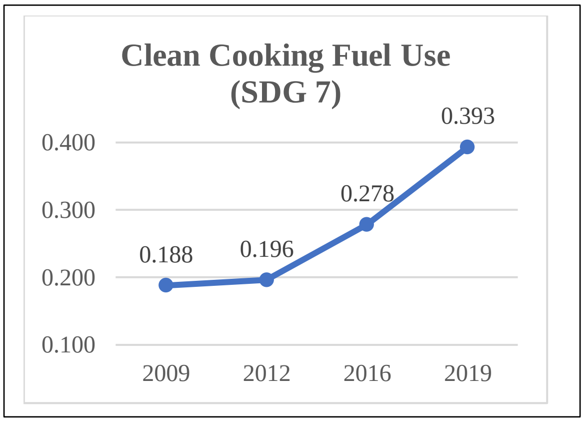

Figure 2.6(b): Clean Cooking Fuel Use

As shown in Figure 2.6(a), the value of the water and sanitation index; the average number of water and sanitation facilities increases over time. The water and sanitation index value was 4.85 in 2009, which increased to 4.92, 4.96, and 5.02 from 2012, 2016, to 2019, respectively. From 2009 to 2019, the use of clean cooking fuels increased continuously (Figure 1.6b).

Since both measures have been rising over time, the change in clean energy (ΔCE) and the change in the water and sanitation index (ΔW) is positive, and as a result, the marginal change is positive (ΔCE/ΔW = 1.21). Therefore, as per the ASA approach, there is an expansion re-linking between SDG 4 and SDG 6, suggesting synergy between the two SDGs. According to the framework for evaluating sustainable development, the shaded area in Figure 2.7 depicts a synergy between SDG 6 and 7.

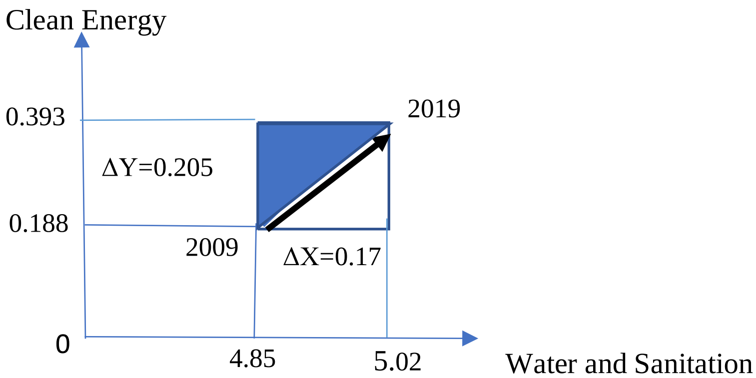

Figure 2.7 – Synergy between Clean Energy and Clean Water

The result is consistent with Fader et al. (2018) and Mainali, Luukkanen, et al. (2018), who found that SDG 6 reinforces the achievement of SDG 7. Mguni et al. (2020) also found that the provision of accessible energy sources would stimulate the availability of clean water. Further, Khan et al. (2014) found that access to energy plays a vital role in providing clean water in many remote locations in Bangladesh. This could happen because having safe drinking water facilities such as tap water inside the house or safe and improved toilet facilities like indoor toilets will facilitate and encourage people to use the kitchen inside of the house. This will enhance the use of clean fuels such as LPG for cooking, which is more convenient to use inside of the dwellings.

In 2010, the Sri Lankan government developed a national policy to ensure clean drinking water and primary sanitation access. As a result, 89.4% of the population used at least basic drinking water services, and 95.85% used basic sanitation services (Sachs et al., 2021). However, the score for SDG 6 is moderately growing (United Nations, 2020), implying that meeting the target by 2030 would be insufficient for Sri Lanka. Since SDG 6 and SDG 7 have a synergistic effect, it is preferable to prioritise the use of safe drinking water and sanitation facilities in national policies, strategies, and action plans. For example, designing a subsidiary programme aimed at people who use contaminated water and sanitation. In addition, the government can connect with the leading water and sanitation suppliers on the market and serve as an intermediary to provide clean water and sanitation services to those who lack them. These kinds of measures will further promote the use of clean cooking fuels, enabling the achievement of both Goals by 2030.

2.5 Conclusion and Policy Implications

This paper analyses the determinants of cooking fuel choice and synergy between SDG 4, 6, and 7 using Sri Lankan HIES data for 2009–2016. The random-effects panel multinomial logit regression findings show that household income, wealth, marital status, age and education of the head, education of the spouse, household size, and the number of children are statistically significant at the 1% level for clean cooking fuel choice. In addition, housing characteristics such as the number of bedrooms, drinking water sources, and housing materials (type of wall, floor, and roof) are also vital for selecting clean fuels for cooking. Moreover, the geographical location (urban and rural sectors) is statistically crucial for obtaining clean cooking fuel compared to the estate sector. These findings have significant implications for meeting SDG 7 by 2030. First, policymakers can address these demographics, socioeconomic, and housing factors when developing a national energy policy. Second, the government can provide monetary incentives, such as subsidies for purchasing efficient cookstoves and modern cooking technologies. Third, government officials can develop informational campaigns throughout the country to raise awareness of the adverse effects of solid fuel use on health and the environment.

Interestingly, we discovered a strong synergy between SDG 4 and SDG 7, indicating that quality education enhances clean fuel use. Similarly, we found that access to clean water encourages clean fuel, indicating synergy between SDG 6 and SDG 7. This finding offers new policy insights for integrating various sector-specific programs and developing consistent cross-sectoral policies. For example, policymakers can create school curricula that teach children about the private and social costs of solid fuel use at a young age. Furthermore, the government can allocate more funds to develop policies that improve basic water and sanitation facilities, encouraging the use of clean fuels. In this way, a country can promote clean energy, clean water, and quality education together, thereby meeting multiple SDG targets simultaneously.

Although a large, nationally representative data set is used in this paper, some of the key variables influencing the choice of cooking fuel, i.e., fuel price, are not included in our current research due to data unavailability. Furthermore, while analyses of synergies and trade-offs can extend beyond SDGs 4, 6, and 7, we have limited them due to a lack of data and to get a deeper understanding of their linkages. Researchers can address these concerns in the future.

2.6 Appendix

Appendix 2A: *Multinomial Logistic Regression Results for Clean Fuel*

Explanatory Variables	(1) FELOGIT	(2) RELOGIT	(3) POMLOGIT
Household Income (log)	0.259***	0.224***	0.102***
	(0.011)	(0.011)	(0.010)
Household Wealth			
Poor Households	1.051***	1.102***	1.243***
(Poorest = 0)	(0.064)	(0.052)	(0.055)
Medium Wealth Households	1.712***	1.786***	2.015***
(Poorest = 0)	(0.066)	(0.051)	(0.055)
Wealthy Households	2.314***	2.415***	2.728***
(Poorest = 0)	(0.068)	(0.052)	(0.057)
Wealthiest Households	3.140***	3.315***	3.750***
(Poorest = 0)	(0.075)	(0.056)	(0.063)
Household Head			
Gender (Female = 0)	-0.204***	-0.044	0.076*
	(0.049)	(0.037)	(0.039)
Marital Status (No = 0)	-0.291***	-0.305***	0.165***
	(0.070)	(0.052)	(0.056)
Age (log Squared)	-0.018*	-0.025***	-0.051***
	(0.009)	(0.007)	(0.008)
Primary Education	0.045	0.025	-0.020
	(0.104)	(0.077)	(0.080)
Secondary Education	0.610**	0.599***	0.491***
	(0.104)	(0.077)	(0.081)
Tertiary Education	1.217***	1.178***	1.255***
	(0.137)	(0.097)	(0.104)
Government Employee	-0.129***	-0.159***	-0.243***
(Other Sector = 0)	(0.041)	(0.030)	(0.032)
Private Sector Employee	-0.301***	-0.460***	-0.371***
(Other Sector = 0)	(0.041)	(0.030)	(0.032)
Spouse			
Age (log Squared)	0.006	0.002	-0.032***
	(0.005)	(0.004)	(0.004)
Primary Education	-0.032	0.027	-0.96
	(0.131)	(0.096)	(0.102)
Secondary Education	0.275**	0.306***	0.081
	(0.130)	(0.095)	(0.100)
Tertiary Education	0.818***	0.857***	0.701***
	(0.161)	(0.115)	(0.123)
Housing Characteristics			
Household Size	-0.149***	-0.143***	-0.139***
	(0.013)	(0.010)	(0.011)
Number of Children Under 5	0.183***	0.185***	0.229***
	(0.032)	(0.023)	(0.025)
Number of Females	-0.029	-0.001	0.010
	(0.018)	(0.014)	(0.015)
Number of Bedrooms	-0.200***	-0.311***	-0.224***
	(0.017)	(0.012)	(0.013)
Drinking Water Source			
Safe Water	0.028	0.123***	0.094**
(Unsafe Water = 0)	(0.061)	(0.045)	(0.047)

Toilet Use			
Indoor Toilets	2.951***	2.040***	1.532**
(No Toilets = 0)	(1.019)	(0.724)	(0.728)
Outdoor Toilets	2.115**	1.171	0.947
(No Toilets = 0)	(1.019)	(0.724)	(0.728)
Improved Toilets	0.024	0.133*	0.221***
(Unimproved Toilets=0)	(0.105)	(0.069)	(0.081)
Type of Wall			
Permanent Wall	0.534***	0.482***	0.354***
(Semi-Permanent = 0)	(0.086)	(0.069)	(0.075)
Type of Floor			
Permanent Floor	-0.003	1.181***	0.161***
(Semi-Permanent = 0)	(0.068)	(0.050)	(0.055)
Type of Roof			
Permanent Roof	-0.540***	-0.462***	-0.409***
(Semi-Permanent = 0)	(0.081)	(0.062)	(0.066)
Sector			
Urban (Estate = 0)	1.501***	1.841***	1.656***
	(0.090)	(0.066)	(0.071)
Rural (Estate = 0)	0.335***	0.261***	0.010
	(0.087)	(0.065)	(0.070)
District Dummy	No	No	Yes
Year Dummy	No	No	Yes
Log pseudo-likelihood	-10306.967	-37881.359	-33771.818
Pseudo R2	0.3979		0.3633
Number of Observations	44,662	79,106	79,106

*****p<0.10, **p<0.05, ***p<0.01**,** robust standard errors in parentheses (1) Fixed effects Multinomial logit (felogit) (2) Random effects Multinomial logit (relogit), and (3) Pooled Multinomial logit (pomlogit).

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Chapter 3: Migration, Remittances and Clean Cooking Fuel: Exploring the Mediating Role of Household Wealth

3.1 Introduction

About 2.4 billion people worldwide use solid fuels like firewood, biomass, and crop residue for cooking, endangering human health and the environment (IEA, 2022). The incomplete combustion of these fuels emits extremely harmful greenhouse gases and directly contributes to indoor air pollution (Balakrishnan et al., 2018; Muller & Yan, 2018). Indoor air pollution has been designated as the world's ninth-largest health risk, accounting for 3.2 million deaths (IEA, 2022). Therefore, the United Nations has adopted Sustainable Development Goal (SDG) 7, ensuring access to affordable, reliable, and modern energy for all by 2030. Modern or clean fuels such as electricity, Liquefied Petroleum Gas (LPG), and solar power are thought to be the golden thread that connects economic growth, human development, and environmental sustainability together (IEA, 2017). As a result, countries are prompted to switch from solid to clean fuels, irrespective of their level of development.

However, present trends indicate that SDG 7 will not be met, as 2.3 billion people will lack access to clean fuels and cooking technologies by 2030 (United Nations, 2020). As a result, researchers are interested in examining the causes of the energy transition, and most have identified household income as a significant determinant (Amoah, 2019; Dash et al., 2018; Ye & Koch, 2021). Households can raise their income from internal and external sources. Migrant remittances, or financial and in-kind transfers made directly by migrants to their families in the origin countries, are currently among the most prominent external income sources in most Low and Middle-Income Countries (LMICs) (Hassan, 2020; IOM, 2019b). Migrant remittances to LMICs reached USD 589 billion in 2021, with a 7.3% increase over the previous year, making them the largest source of foreign exchange revenue (World Bank, 2021).

As a result, migrant remittances have a great potential to be used as a source of income to encourage clean fuel consumption. A few studies have looked into the impact of migrant remittances on fuel consumption (Hassan, 2020; Manning & Taylor, 2014; Taylor et al., 2011; Ye & Koch, 2021). However, a clear link between migrant remittances and clean fuel usage is challenging to establish as many factors drive the use of remittances. For example, remittance is a flow variable rather than a stock, and therefore, it may not promote clean energy spending directly even if it induces current expenditure. Thus, if energy spending is to be induced, it must be more closely related to stock variables like education and health (Hassan, 2020).

Despite this, previous research shows that migrant remittances substantially affect household wealth (Baiyegunhi & Hassan, 2014; Rahut et al., 2016), whereas household wealth significantly influences clean fuel consumption (Adams & Cuecuecha, 2010; Mahapatro, 2016). This would happen because wealth is a stock variable rather than a flow variable, and therefore, it is likely to influence the use of clean fuel. As a result, this paper integrates two distinct pieces of literature: remittances and energy, through household wealth. Based on this background, this study seeks to address three research questions: (1) does clean cooking fuel consumption differ between migrants and non-migrants? (2) do migrant remittances influence the type of cooking fuel used? (3) does household wealth mediate the relationship between migrant remittances and the type of cooking fuel used?

As a result, this study has threefold contributions to the literature. First, to the best of our knowledge, this will be the pioneering study to employ household wealth as a mediating variable to examine the impact of migrant remittances on the type of cooking fuel used. The paper's uniqueness stems from integrating two disparate research areas, namely remittances and energy, through household wealth. Second, this will be the first study to compare the use of clean fuel for cooking between migrant and non-migrant households, based on nationally representative data from over 78,000 households. This paper uses repeated cross-sectional data from Sri Lankan Household Income and Expenditure Surveys (HIES) for 2009, 2012, 2016 and 2019. Third, this paper isolates migrant remittances as a driver of household fuel choice, which has received less attention in earlier research.

The remainder of this paper is organized as follows. Section 2 briefly reviews the relevant literature. Sections 3 and 4 outline the data and variable descriptions and the empirical model. Section 5 describes the results and discussion. Finally, section 6 concludes the paper and discusses the policy implications.

3.2 Literature Review

Solid fuels produce harmful gases such as carbon dioxide (CO_2), carbon monoxide (CO), and particulate matter ($PM_{2.5}$), endangering human health and the environment (Desai et al., 2004; Smith & Mehta, 2003). Due to the extremely negative implications of using solid fuels, extensive research has been performed to determine the factors that induce households to move from solid to cleaner fuels. Household income[14], household wealth[15], price of fuels[16], head and

[14] Amoah, 2019; Dash et al., 2018; Ravindra et al., 2019; Song et al., 2018; Ye & Koch, 2021

[15] Baiyegunhi & Hassan, 2014; Ouedraogo, 2006; Rahut et al., 2016

[16] Baiyegunhi & Hassan, 2014; Guta, 2014; Ravindra et al., 2019; Sharma et al., 2020

spouse characteristics[17] (age, gender, marital status, and education level), household size[18], number of children[19] and females[20], housing characteristics[21] (water and sanitation facilities, type of wall, roof, and floor), residential area[22] (urban vs rural), accessibility and availability of fuels[23], and taste preferences[24] are among the major determinants highlighted by these researchers.

Furthermore, the energy transition process is explained by two primary theories; the *energy ladder hypothesis* and the *energy stacking theory*. The energy ladder hypothesis states that when a household's socioeconomic status improves, particularly their income, they shift from solid fuels to transitional fuels and eventually to cleaner fuels (Heltberg, 2004; Hosier & Dowd, 1987; Leach, 1992). On the contrary, the energy stacking theory asserts that as a person's economic status improves, they consume a portfolio of energy sources, including more clean fuels (Amoah, 2019; Heltberg, 2005; Ravindra et al., 2019; Sharma et al., 2020). Therefore, both theoretically and empirically, household income has been recognised as the most crucial driver of clean fuel use.

To enhance household income, most LMICs currently rely on international migration, i.e., a movement of people away from their habitual residence across an international boundary (IOM, 2019a). The New Economics of Labour Migration (NELM) theory states that migration is not an individual decision but rather a family decision to improve socioeconomic conditions and well-being in one's home country (Stark & Bloom, 1985). Numerous studies have been conducted to discover the causes of migration and the benefits it brings, notably in terms of health and education.

However, although energy access and its use are essential aspects of people's socioeconomic conditions and welfare (Broto et al., 2017), it is rarely acknowledged as a factor in migration decisions and benefits. As a result, the link between international migration and the usage of clean fuels is currently a point of contention among scholars, but it remains restricted. Scott et al. (2018) argue migration can help to achieve SDG target 7.1, ensuring universal access to modern, reliable, and affordable energy. Manning and Taylor (2014) showed that migration aids the transition from fuelwood to gas for cooking in Mexico. Similarly, migrant families in

[17] Mensah & Adu, 2015 ; Sharma et al., 2020 ; Baiyegunhi & Hassan, 2014
[18] Sharma et al., 2020 ; Baiyegunhi & Hassan, 2014; Mensah & Adu, 2015
[19] Baiyegunhi & Hassan, 2014
[20] Dash et al., 2018; Rahut et al., 2016 ; Rahut et al., 2017
[21] Heltberg, 2005; Sharma et al., 2020
[22] Mensah & Adu, 2015; Rahut et al., 2016
[23] Mensah & Adu, 2015; Sharma et al., 2020; Song et al., 2018
[24] Dash et al., 2018; Heltberg, 2005; Ravindra et al., 2019; Sharma et al., 2020.

Guatemala use multiple cooking fuels than non-migrants (Taylor et al., 2011). However, no research has been done to investigate how migration affects the various types of fuels used at the household level.

The effects of migration on clean fuel consumption in origin countries can be seen in three ways: (1) reducing the number of females; (2) transferring knowledge and skills; and (3) sending remittances. First, if a family has many female migrants, the household might switch to clean fuels because fuelwood collecting diminishes as the number of females falls (Scott et al., 2018). Second, migrant resilience to fuel access obstacles or shocks can be improved with knowledge from other contexts (Maller, 2011). Most migrant-heavy households have higher average income levels, enabling better access to modern energy services. Moreover, migrants working in more advanced countries can experience and gain knowledge about the benefits of using clean energy such as solar home systems, modern electrical appliances, and modern cooking methods. Thus, migrants can transfer this knowledge to their families while they remain in their place of destination or, more significantly, when they return (Scott et al., 2018), and this was validated by Sulthana (2015).

Finally, migrant remittances are inextricably related to migration, and they provide economic support and self-insurance to millions of households in underdeveloped nations at the micro-level (Akçay & Demirtaş, 2015; Taylor, 1999). Much evidence suggests that remittance recipients have a higher standard of living than non-remittance recipients, owing to better social conditions. Remittance recipients, for example, are more likely to use modern, clean fuels than non-remittance recipients. In Bangladesh, Hassan (2020) discovered that remittances enhance the likelihood of utilizing LPG for cooking by recipient households. In Ghana, Bukari et al. (2021) found that the negative impact of energy poverty on household health expenses is considerably mitigated through remittances. According to Mendelson (2013), remittance income is used for various sustainable energy technologies in developing countries. In Ecuador, a clean energy technology programme has been coupled with a financial remittance mechanism to boost rural energy access (IFAD, 2009). Moreover, households in Morocco use remittances for short-term and long-term energy consumption (Akçay & Demirtaş, 2015), and in Tajikistan, remittances are used to pay for energy services (World Bank, 2015). Also, the 3x1 Migrant Program in Mexico directs remittances to invest in local development, such as electrification projects (Orozco & Lapointe, 2004).

In theory, with an increase in income, two underlying factors cause households to switch to cleaner fuel sources (Hanna & Oliva, 2015). First, because solid fuels are inherently inferior goods and clean fuels are normal goods, the substitution effect towards clean fuels can outweigh the wealth effect due to greater household well-being. Second, awareness of the adverse health consequences of using dirty fuel will strengthen the substitution effect of clean fuels. The source of income, in general, does not affect the extent of the substitution effect. Yet, the rise in household income from specific sources, such as migrant remittances, could affect the substitution effect in some circumstances. Because remittances are usually invested in boosting human capital, they are more cautious about safeguarding their health capital (Hassan, 2020).

However, establishing a clear link between remittances and the use of clean fuel remains a challenge theoretically or empirically, prompting further investigation. As a result, this paper adds a new dimension and integrates two distinct pieces of literature: remittance and energy, through household wealth. Household wealth is generally measured by the wealth index, and it incorporates the long-term impacts of household well-being. The wealth index is often constructed using the number of durable household assets, water and sanitation facilities, and housing characteristics like the number of bedrooms, house ownership, housing area, type of wall, roof, and floor (Balen et al., 2010; Chasekwa et al., 2018; Gupta et al., 2017; Guta, 2014; Rahut et al., 2016; Song et al., 2018).

Most studies have discovered a significant positive association between household wealth and clean fuel use in the energy literature. Rahut et al. (2016) stated that wealthy families with permanent floors, roofs, and walls were more likely to use cleaner fuels. Having more rooms and piped water also enhances the possibility of using clean fuels (Arthur et al., 2010; Heltberg, 2004, 2005). Furthermore, in Nigeria, Baiyegunhi and Hassan (2014) show that families who reside in traditional dwellings are more likely to use clean fuels. According to Lay et al. (2013), homeowners utilize more clean fuels than tenants. Nevertheless, some studies have found the contrary (Ouedraogo, 2006; Pundo & Fraser, 2006).

Research on migrant remittances, on the other hand, indicates that they have a significant impact on household wealth. Households that receive remittances are more likely than non-recipients to invest in productive assets (Adams & Cuecuecha, 2010; Ajaero et al., 2018; Ajefu, 2018; Mahapatro, 2016; Yousafzai, 2015). Specially in housing, land, education, health, and repaying debts (Abainza & Calfat, 2018; Ajaero et al., 2018; Mahapatro, 2016; Mahapatro et al., 2017), and therefore, they are benefited from higher living standards. Given this context, the following hypotheses are tested in this study.

H_1: Migrant families use more clean fuel for cooking than non-migrant families

H_2: There is a direct, positive relationship between migrant remittances and clean cooking fuel

H_3: There is a direct, positive relationship between migrant remittances and transitional cooking fuel

H_4: There is a direct, positive relationship between migrant remittances and household wealth

H_5: There is a direct, positive relationship between household wealth and clean cooking fuel

H_6: There is a direct, positive relationship between household wealth and transitional cooking fuel

H_7: Household wealth mediates the relationship between migrant remittances and the type of cooking fuel use

3.3 Data and Variable Description

Sri Lanka is an intriguing study context to investigate the issues of energy and migration. Because although the country achieved universal access to electricity in 2019, clean cooking remains a challenge, with nearly 15 million people (69%) relying on biomass to cook (IEA, 2021). Jayasinghe et al. (2021) also found that the most pressing issue of energy poverty in Sri Lankan households is a lack of access to modern cooking fuel. Furthermore, worker remittances account for 8.8% of the Gross Domestic Product, amounting to USD 7104 million (CBSL, 2020).

3.3.1 Data Description

This study uses cross-sectional repeated data for four waves of (2009, 2012, 2016 and 2019) Household Income and Expenditure Surveys (HIES). The Department of Census and Statistics in Sri Lanka conducts HIES every three years and provides essential socioeconomic indicators. It uses direct interviews and a survey questionnaire to collect data on demographics, income, expenditure, school education, health, and household assets.

The survey's sample design is stratified into two stages, and urban, rural, and estate sectors in each district serve as selection domains for stratification. A selection of 2500 primary sampling units was chosen from the sampling frame for the survey at the primary stage. From each primary sampling unit, 10 housing units were chosen for the survey. In 2009, 2012, 2016 and 2019, the total sample sizes were 23 641, 25 319, 25 640 and 24 922 dwelling units. However, only 19 958, 20 540, 21 756, and 19 911 households replied each year, for a total of 81 365 households, and we ended up with 78 931 households for the study after removing the missing values of variables interested in the study.

3.3.2 Variable Description

The dependent variable of the study is cooking fuel consumption. Based on the energy ladder theory, we divide cooking fuel choice into three categories: (1) solid fuels (fuelwood, saw/paddy husk, and other); (2) transitional fuels (kerosene); and (3) clean fuels (LPG and electricity). Figure 3.1 shows the distribution of households by primary cooking fuel consumption in Sri Lanka.

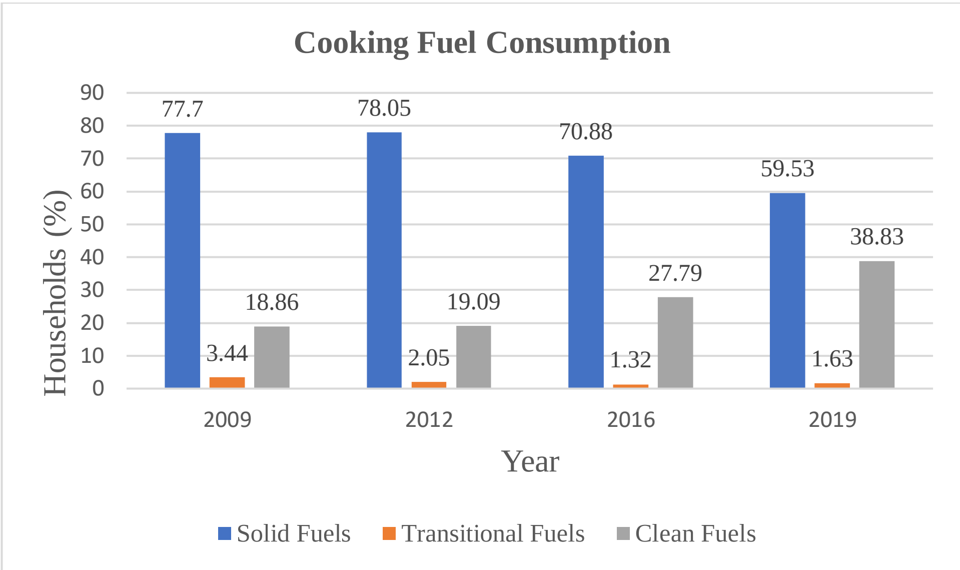

Figure 3.1 Cooking Fuel Consumption

According to Figure 3.1, most Sri Lankan families use solid fuels as their primary cooking fuel, but this has declined over time (from 78% in 2009 to 60% in 2019). The proportion of households using transitional fuels has decreased over the periods, whereas the proportion of households using clean fuels has steadily increased (18.76%, 19.82%, 27.93%, and 38.83% for 2009, 2012, 2016, and 2019 respectively).

The independent variable of the study is migrant remittances. To have better-behaved data distributions, we use the natural logarithm (log) of remittances to validate normality. We use the household wealth index as the mediating variable in the relationship between migrant remittances and the type of cooking fuel used. The study's control variables include the other household[25] income, age of the head[26] and the spouse (log), gender of the head (male and female), education of the head and the spouse (no schooling, primary, secondary, and tertiary), head's employment sector (government, private, and other sectors), household size[27], the

[25]Household is defined as a group of persons who live together and has a common arrangement for cooking.

[26] Head of household is a person who usually resides in the household and is acknowledged by the other members of the household as the head of the household.

[27] Household size refers to the number of persons usually living in the household, including boarders and servants.

number of children under the age of five, the number of females, the residential sector[28] (urban, rural, and estate sector), and the districts (25 districts). In addition, categorical variables were dummy coded, with each of them having the following reference categories: solid fuels for cooking fuel type, female for head's gender, no schooling for education, other sectors for head's employment sector, estate sector for residential area, and Colombo district for district variable.

The descriptive statistics of the variables studied are reported in Table 3.1. It shows that around 8% of families have at least one migrant member, with an average remittance of SL Rs.17,403 (US$ 48.34, converted to US$1 = SL Rs.360). The average wealth quintile is 3, indicating that most families are middle-income. Males account for the majority of the heads of households. The head and spouse are, on average, 52 and 33 years old, respectively. The head has a grade 9 education, whereas the spouse has an average grade 7 education. The average household size is four individuals, comprising two women. Rural areas account for 72.6% of all households.

Table 3.1: Descriptive Statistics

Variable	Mean	Std. Dev.
Cooking Fuel Type	1.375	0.644
Migrant Remittances	17403.45	116184.9
Migrants	0.077	0.267
Household Income	126790	931081
Wealth Index Quintiles	3.006	1.412
Head Gender	1.247	0.43
Head Age	52.13	14.07
Head Education	8.886	3.940
Head Employment Sector	1.586	1.977
Spouse Age	33.66	23.44
Spouse Education	6.870	5.277
Household Size	4.145	1.695
Female Number	2.136	1.151
Children Number	0.234	0.511
Urban Sector	0.208	0.406
Rural Sector	0.726	0.446

3.4 Empirical Model

This study addresses three research questions. We begin by identifying the differences between migrants and non-migrants in their use of clean fuel for cooking. To accomplish this, we employ the Propensity Score Matching (PSM) method (Arsenijevic & Groot, 2018; Clément, 2011; Démurger & Wang, 2016). Second, we examine the impact of migrant remittances on the type of cooking fuel used. For that, we use a control function approach due to the possible

[28] Rural sector includes all the areas other than the areas governed by Municipal Councils (MCs) and Urban Councils (UCs) and the estate sector (Census and Statistics Department, 2012)

endogeneity of remittances (Petrin & Train, 2010; J. Wooldridge, M., 2015). Finally, we utilize instrumental variable mediation analysis to determine how household wealth mediates this relationship (Dippel, 2017; Joffe et al., 2008). We use Principal Component Analysis (PCA) to construct the household wealth index (Chasekwa et al., 2018; Filmer & Pritchett, 2001; Vyas & Kumaranayake, 2006) (see Appendix 3B).

3.4.1 Propensity Score Matching Method (PSM)

The primary purpose of using PSM analysis is to quantify the average effect of migrant households (treatment group) on non-migrant households (control group) who have similar characteristics. The estimated average impact on the treated group can be derived as follows.

Suppose the treatment (T_i) is equal to “1” if household “i” receives remittances and if not “0”. Y_{i1} is the potential outcome of household i who receive remittances and otherwise Y_{i0}. The difference between the outcome indicator of the treatment group and the control group is then used to calculate the average treatment effect for the i^{th} household.

$$\Delta Y_i = E\left(Y_{it|}\, T_i = 1\right) - \left(Y_{i0|}\, T_i = 1\right) \quad (3.1)$$

The main assumption of the PSM analysis is the Conditional Independence Assumption (CIA), which states that treatment selection is exclusively dependent on observed variables (Caliendo & Kopeinig, 2008; Nannicini, 2007; Rosenbaum & Rubin, 1983). The observed variables are denoted by X and can be expressed as follows.

$$\left(Y_{i0|}\, T_i\right) \perp T_{i|}\, X_i \quad (3.2)$$

Equation 2 shows, given X_i, the outcome of the control group can approximate the counterfactual outcome of the treated group in the absence of treatment. Accordingly, the outcome is given as:

$$E\left(Y_{i0|}\, T_i = 1,\ X_i\right) - \left(Y_{i0|}\, T_i = 0,\ X_i\right) \quad (3.3)$$

This illustrates the propensity score represents the probability of treatment conditional on a vector of observable characteristics and may be interpreted as the one-dimensional summary of the set of observable variables, which is expressed as:

$$P\ (Xi) = Pr(\ T_i = 1|X_i\ ) \quad (3.4)$$

The estimation of the counterfactual is given as:

$$E\left[\left(Y_{i0|}\, T_i = 1, P(X_i)\right)\right] = E\ [\left(Y_{i0|}\, T_i = 0, P(X_i)\right)] \quad (3.5)$$

Finally, the average treatment effect for i[th] household is measured as follows.

$$\Delta Y_i = E\left[\left(Y_{i0|}\ T_i = 1, P(X_i)\right)\right] = E\ [(Y_{i0|}\ T_i = 0, P(X_i)] \tag{3.6}$$

3.4.2 Control Function Approach

To analyse household cooking fuel choices, we employ a random utility model. Accordingly, a household chooses between three mutually exclusive cooking fuel options: solid, transitional, and clean, to maximize their utility. The utility that household *n* obtains from alternative *j* is given by (Petrin & Train, 2010; Vadean et al., 2019):

$$U_{nj} = V\left(\ Rem_{nj}, X_{nj}, \beta_n\right) + \ \varepsilon_{nj} \tag{3.7}$$

where U_{nj} is the utility that depends on observed factors, Rem_{nj} stands for the amount of remittances received by the household *n*, X_{nj} is a vector 14 of exogenous variables that affect the utility derived from choice *j*, β_n is the parameters that present the taste of households, and ε_{nj} is the unobserved utility.

However, the amount of remittances a household receives is most likely endogenous (Adams & Cuecuecha, 2013; Demirgüç-Kunt et al., 2011). In choice models, the control function (CF) approach is one of the most effective and straightforward ways to deal with endogeneity (Petrin & Train, 2010; Piracha et al., 2013; J. M. Wooldridge, 2015). The CF method is a robust two-step approach in which the amount of remittances is represented as a function of observed and unobserved parameters in the first phase as follows:

$$Rem_{nj} = W(Z_n, X_n, \gamma) + \mu_{nj} \tag{3.8}$$

where ε_{nj} (in equation 7) and μ_{nj} are independent of Z_n and X_n, but ε_{nj} and μ_n are correlated. The vector Z_n contains a set of instruments that are correlated with Rem_n but not enter directly the utility function U_{nj}. Following Petrin and Train (2010), it is decomposed into a part that can be explained by a general function of μ_n and a residual:

$$\varepsilon_{nj} = CF(\mu_n, \lambda) + \ \tilde{\varepsilon}_{nj} \tag{3.9}$$

where $CF(\mu_n, \lambda)$ denotes the control function with parameters λ. We specify the control function as linear in μ_n (i.e., $F(\mu_n, \lambda) = \lambda\mu_n$), giving utility the following form:

$$U_{nj} = V\left(Rem_{nj}, X_n, \beta_j\right) + \lambda\mu_{nj} + \ \tilde{\varepsilon}_{nj} \tag{3.10}$$

Conditional on μ_n, the probability that household *n* chooses alternative *i* is equal to:

$$P_{ni} = \iint I(U_{ni} > U_{nj} + \lambda\mu_n + \tilde{\varepsilon}_{nj} \ \forall \ j \neq i) f(\beta_n, \tilde{\varepsilon}_n) d\beta_n d\tilde{\varepsilon}_n \quad (3.11)$$

Where f (.) is the joint density of β_n and $\tilde{\varepsilon}_n$ and I (.) is the indicator function.

In this way, the control function is added to the conventional choice model as an extra explanatory variable. The model is estimated in two steps. First, Equation 8 is estimated by OLS with the endogenous variable (Rem_n) as the dependent variable and the exogenous variable and the instrument (i.e., Z_n and X_n) as explanatory variables, following the exclusion restriction procedure of the instrument. Then, using the estimated parameters ŷ from the OLS regression, the residual is calculated as ($\hat{\mu}_{nj} = Rem_{nj} - W(Z_n, X_n, \gamma)$). In the second step, the choice model is estimated using multinomial logit regression (see Appendix 3C) by taking $\hat{\mu}_n$ as an additional covariate.

The choice of an appropriate instrument that satisfies both instrument relevance and exclusion restriction criteria is crucially essential to address the endogeneity of remittances. As a result, the choice of an instrumental variable differs across various studies. Some studies have employed *monthly rainfall data* as the instrumental variable to address the endogeneity of remittances (Akobeng, 2022; Yang & Choi, 2007). The rationale behind this instrument is that rainfall is a crucial element in determining the output of rain-fed crops, which create the majority of household income in countries with subtropical monsoon climates. Therefore, it is an excellent predictor of remittances that respond to household income shocks (Yang & Choi, 2007). In addition, some studies have employed *distances* such as *the distance to the railway station* (Adams & Cuecuecha, 2010, 2013; Ambrosius & Cuecuecha, 2016), or *the distance to the city* (Demirgüç-Kunt et al., 2011) as the instrument depending on the study context and the data availability.

Many studies have used distance to the nearest bank as the instrument to examine the association between financial inclusion and energy poverty (Awaworyi Churchill et al., 2020; Koomson & Danquah, 2021; Koomson et al., 2020). The instrument of distance to the nearest bank also serves as an excellent tool for addressing the endogeneity of remittances because most migrant families are financially inclusive, with bank accounts and access to banking to perform routine banking operations such as withdrawing cash from remittance receipts. Furthermore, due to the rapid expansion of global money transfer infrastructure and lesser restrictions, most remittances are now channelled through official banking sources (Ahmed et al., 2021; Guermond, 2022). Thus, it is reasonable that migrant households will be relocating closer to a bank to lower the transaction costs of frequent visits to a bank or other financial institutions. As a result, we predict that the log of remittances and the distance to the nearest bank will have a negative first-stage relationship. A study conducted by Hassan (2020) in Bangladesh used rainfall interaction with cyclone-affected migrant households' distance to the local weather stations as an instrument to address the endogeneity of remittances. For this reason, we employed *average province rainfall times the log of distance to the nearest bank* as the instrument to address the endogeneity of remittances.

More significantly, the instrument satisfies the two conditions of a valid instrument: relevance and exogeneity (Stock & Watson, 2007; J. Wooldridge, M., 2015). If the instrument is more relevant, it can explain the greater variation in the endogenous regressor (log of remittances) without necessarily being correlated with the unobserved factors that influence the outcome variable (cooking fuel type). This criterion is satisfied when the first stage F statistics exceed the rule-of-thumb value of 10 (Stock & Yogo, 2005). The second condition, exogeneity, explains that the instrument cannot directly affect the type of cooking fuel and can only affect the type of cooking fuel through remittances to obtain a consistent estimation. Since there are no direct tests for the exclusion restriction, we run auxiliary regressions to help us identify variables in our model that could be potential exclusion restriction violators because they are correlated with the instrument. Afterwards, we incorporate them into the empirical model as covariates to ensure they have no direct relationship with the dependent variable of the structural equation. The process provides a credible identification and supports the instrument's validity (see Table 3A.1 and 3A.2 in Appendix 3A).

3.4.3 Instrumental Variable Mediate Model (IV Mediate)

One of the primary objectives of this study is to determine the mediating effect of the wealth index on the association between migrant remittances and the type of cooking fuel used. We observed that remittances and wealth index are endogenous variables using the endogeneity test (the predicted residual is significant in the second stage). Since both the treatment variable and the mediators are endogenous, a single instrumental variable is sufficient to determine the causal and mediation effects (Dippel, 2017; Joffe et al., 2008). Following that, we employ the IV mediate model with a single instrument (Dippel et al., 2020; Dippel et al., 2019).

First, we define the linear equations for remittances (Equation 3.13), wealth index (Equation 3.14) and cooking fuel type (Equations 3.15 – 3.17) as follows:

$$lnRDB = \varepsilon_{RDB} \ , \tag{3.12}$$

$$lnRem = \beta_{Rem}^{RDB}.RDB + \varepsilon_{Rem} \ \ , \tag{3.13}$$

$$WI = \beta_{WI}^{RDB}.RDB + \varepsilon_{WI} \ \ , \tag{3.14}$$

$$CF_1 = \beta_{Rem}^{RDB}.RDB + \beta_{WI}^{DB}.RDB + \varepsilon_{CF1,} \tag{3.15}$$

$$CF_2 = \beta_{Rem}^{RDB}.RDB + \beta_{WI}^{RDB}.RDB + \varepsilon_{CF2} \, , \tag{3.16}$$

$$CF_3 = \beta_{Rem}^{RDB}.RDB + \beta_{WI}^{RDB}.RDB + \varepsilon_{CF3} \tag{3.17}$$

where RDB is the instrumental variable (average province rainfall data multiplied by the log of distance to the nearest bank), $lnRem$ is the log of migrant remittances (treatment), WI is wealth index (mediator), CF is cooking fuel type (outcome, where 1,2 and 3 are solid, transitional and clean fuels, respectively) and $\varepsilon_{WI}, \varepsilon_{Rem}, \varepsilon_{II}, \varepsilon_{EP1}, \varepsilon_{EP2}, \varepsilon_{EP3}$ are error terms, respectively. We assume ε_{RDB} is statistically independent of other error terms.

The direct effect is given by the coefficient $DE = \beta_{EP}^{II}$, the indirect effect is given by the coefficient multiplication $IE = \beta_{II}^{Rem}.\beta_{EP}^{II}$, and total effect is the sum of these two terms $TE = \beta_{EP}^{II} + \beta_{II}^{Rem}.\beta_{EP}^{II}$.

3.5 Results & Discussion

3.5.1 Propensity Score Matching (PSM) Results

This section compares how migrants and non-migrants use clean fuel for cooking. We employed the PSM model, with migrants serving as the treatment group (8%) and non-migrants serving as the control or comparison group. We use the migrants as a dummy variable, coding “1” for migrants and “0” for non-migrants. To estimate propensity scores, we selected 13 covariates[29] to avoid reverse causality and to have no effect on household expenditure patterns. However, household income was not included as a covariate since it directly impacts household expenditure patterns, leading to endogeneity bias (Clément, 2011).

As the first step of estimating the propensity score, we used probit regression to identify the relationship between covariates and the treatment variable. The results are shown in Table 3.2 and the explanatory power of the probit model is satisfactory, with a probability Chi-squared value less than 0.05 (Prob > Chi2 is 0.000) and a McFadden Pseudo R-squared value of 11.48%.

[29] Wealth index, head and spouse characteristics (gender, age, education, and employment sector), household characteristics (household size, number of children, and number of females), and residential sector (urban and rural).

Table 3.2: Probit Estimation for Propensity Score

Migrants	Coefficient	Standard Error	z	P > z
Wealth Index	0.080	0.004	21.18	0.000
Head Male	0.079	0.023	3.47	0.001
Head Age (log)	-0.687	0.031	-22.40	0.000
Head Education	-0.007	0.002	-3.64	0.000
Head Government Sector	-0.580	0.020	-29.34	0.000
Head Private Sector	-0.497	0.020	-25.05	0.000
Spouse Age (log)	-0.036	0.008	-4.45	0.000
Spouse Education	-0.032	0.003	-11.68	0.000
Household Size	-0.027	0.006	-11.68	0.000
Female Number	0.209	0.009	23.37	0.000
Children Number	-0.200	0.031	-0.62	0.000
Urban Sector	0.138	0.037	4.12	0.000
Rural Sector	-0.019	0.031	-0.62	0.533
Pseudo R-square	0.1148			
Log-likelihood	-19042.346			
LR Chi2	4941.08			
Number of Observations	78,931			

The findings suggest that apart from the rural sector, all other covariates are significantly associated with the treatment group at the 1% significance level. For example, the wealth index, gender of the head, number of females, and urban sector are positively associated with the treatment group, whereas other covariates are negatively associated.

Next, we ensure the condition for common support by examining whether the propensity scores in the treatment and control groups are overlapping and balanced. To ensure this, we divided the observations into five propensity score quintiles (see Figure 3.2).

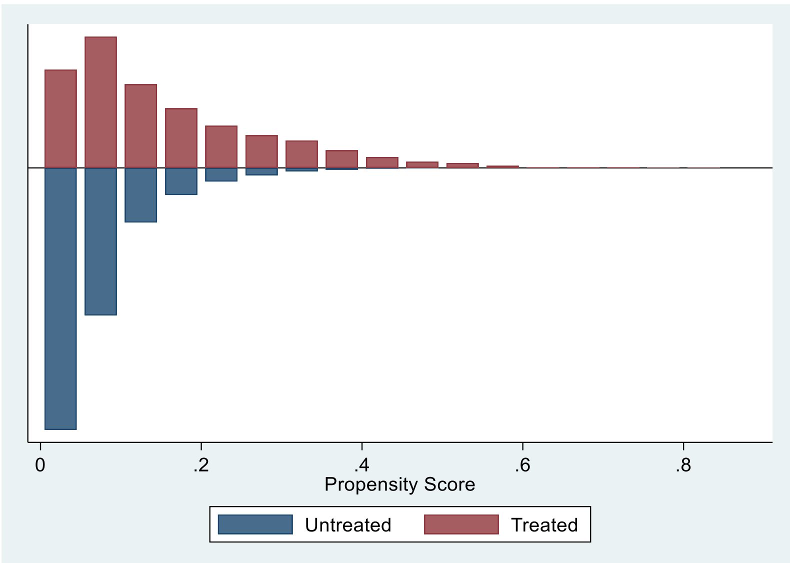

Figure 3.2. Distribution of Propensity Score across Treatment and Control Groups

The propensity score distributions of the two groups in the graph include 78,931 observations (6,115 treated and 72,816 untreated). The results reveal that the degree of overlap is satisfactory as the mean propensity score is equivalent in the treatment and comparison groups within each of the five quintiles in our final propensity score specification (Imbens, 2004).

After creating a balanced propensity score, we calculated the Average Treatment Effects on the Treated (ATT) to compare treatment and control groups, and the estimates are in Table 3.3.

Table 3.3: Propensity Scores for the Unmatched and Matched Sample

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Clean Fuel	Unmatched	0.295	0.186	0.109	0.005	20.73
	Matched /ATT	0.295	0.238	0.057	0.009	6.67

The mean difference between migrants and non-migrants in choosing clean fuel was measured using a T-test, and it was shown to be significant. According to the unmatched analysis, migrants are 10.9% more likely to use clean fuels than non-migrants. Using the matching method, or ATT, migrants use 5.7% more clean fuel for cooking than non-migrant households.

To check the robustness of the results, we computed the Average Treated Effect (ATE) and Average Treated Effect on Treated (ATET) using the same covariates. The ATE was calculated using two estimators: nearest-neighbour (NN) matching and propensity score (PS) matching. The results are depicted in Table 3.4.

Table 3.4: ATE and ATET values from Propensity Score Matching

Variable	AI Robust		z	p
Clean Cooking Fuel	Coefficient	Std. Error		
ATE (NN matching)	0.070	0.009	7.09	0.000
ATE (PS matching)	0.083	0.009	9.39	0.000
ATET	0.057	0.008	7.00	0.000

According to the NN matching and PS matching methods, migrant households use 7% and 8.3% more clean fuels for cooking than non-migrant households, respectively. The ATET result shows that migrants use 5.7% more clean fuels than non-migrants, which is exactly the same as ATT estimates. Overall, all the estimates show that migrant families consume more clean fuels for cooking than non-migrant families.

The PSM approach is based on the Conditional Independence Assumption (CIA), which states that treatment selection is exclusively dependent on criteria that the researcher can observe (Caliendo & Kopeinig, 2008; Nannicini, 2007). However, if unobserved variables affect treatment assignment and potential outcome variables simultaneously, a hidden bias might arise. If hidden biases are present, matching estimators are not robust. Therefore, to address this issue, we use simulation-based sensitivity analysis, and it is recommended to use an additional binary variable to calculate the matching estimator (Nannicini, 2007). Thus, we use *house ownership* as an additional covariate with the NN matching estimation to calculate ATT. The ATT value was 0.051, and it indicates that migrant households use 5.1% more clean fuels for cooking than non-migrant households, which is consistent with our previous results.

Overall, the findings reveal that migrants use more clean fuels for cooking than non-migrants, rejecting the first (H_1) null hypothesis. This finding is consistent with the findings of Manning and Taylor (2014) in Mexico. They discovered that migration boosts gas expenditure by around 160% while decreasing their reliance on firewood in rural households. This could be because migrant families are experiencing increased labour shortages, specially in terms of female numbers, thereby raising the implicit cost of firewood. Furthermore, migrants utilize more modern energy sources due to greater remittances and the transfer of energy-related knowledge (Scott et al., 2018). However, Taylor et al. (2011) observed that migrant households in Guatemala use various fuels and cooking methods rather than a complete transition from fuelwood to LPG. These findings suggest that the type of cooking fuel used by migrants differs depending on the study context. Yet, our findings demonstrate 'energy access' as a factor in migration decision-making and one of the benefits of migration that is not addressed in the migration theories.

3.5.2 Control Function (CF) Results

The main objective of this study is to identify the impact of remittances on the use of clean fuel for cooking. Since remittance is endogenous, we use the CF approach to address the endogeneity. As described in Section 4.2, the *average province rainfall interacted with the log of distance to the nearest bank* was used as the instrumental variable. The OLS regression was run with the instrument under each of the three models, taking log remittance as the dependent variable. The F-test value for all the models is greater than 10, suggesting that the instrument is valid according to the rule of thumb (J. Wooldridge, M., 2015). Then we predicted the OLS residual and substituted it into the multinomial logit model as an additional covariate in the second stage for each model separately. The results are presented in Table 3.5.

Table 3.5: CF Estimates

Variables	Model (1)		Model (2)		Model (3)	
	Clean Fuels	Trans. Fuels	Clean Fuels	Trans. Fuels	Clean Fuels	Trans. Fuels
Migrant Remittances (log)	4.136*** (0.090)	4.099*** (0.133)	3.516*** (0.104)	3.338*** (0.155)	3.717*** (0.120)	3.590*** (0.176)
Head's Characteristics						
Gender	2.630*** (0.064)	2.508*** (0.093)			-0.113*** (0.042)	-0.093*** (0.061)
Age (log)	2.790*** (0.078)	2.573*** (0.113)			4.069*** (0.142)	3.679*** (0.209)
Marital Status	1.026*** (0.091)	1.233*** (0.123)			1.601*** (0.111)	1.548*** (0.156)
Primary Education	-0.476*** (0.088)	-0.681*** (0.115)			-0.500*** (0.096)	-0.579*** (0.126)
Secondary Education	0.503*** (0.088)	-1.445* (0.218)			0.136 (0.102)	-0.557*** (0.138)
Tertiary Education	3.304*** (0.104)	-0.197*** (0.116)			1.751*** (0.118)	1.107*** (0.148)
Employment Sector -	4.183*** (0.105)	4.243*** (0.155)			3.796*** (0.140)	3.792*** (0.205)
Employment Sector - Private	3.592*** (0.091)	3.581*** (0.133)			3.290*** (0.124)	3.260*** (0.181)
Spouse's Characteristics						
Age (log)			0.659*** (0.027)	0.653*** (0.039)	0.442*** (0.022)	0.444*** (0.031)
Primary Education			0.624*** (0.119)	0.274* (0.151)	0.549*** (0.122)	2.293*** (0.153)
Secondary Education			2.253*** (0.118)	1.427*** (0.150)	2.230*** (0.127)	1.599*** (0.162)
Tertiary Education			4.725*** (0.144)	3.628*** (0.179)	4.048*** (0.156)	3.249*** (0.198)
Other Characteristics						
Other Household Income (log)			-0.074*** (0.012)	-0.112*** (0.018)	-0.172*** (0.014)	-0.211*** (0.021)
Household Size			0.031*** (0.011)	0.046*** (0.108)	0.057*** (0.012)	0.063*** (0.016)
Number of Females			-1.397*** (0.046)	-1.596*** (0.332)	-1.402*** (0.049)	-1.404*** (0.072)
Number of Children			0.696*** (0.028)	0.359*** (0.068)	1.432*** (0.050)	1.379*** (0.072)

Urban Sector			1.349*** (0.079)	2.492*** (0.200)	1.537*** (0.076)	1.546*** (0.107)
Rural Sector			0.750*** (0.071)	1.228*** (0.278)	0.882*** (0.075)	0.726*** (0.103)
District Dummy	Yes		Yes		Yes	
First Stage F Statistic	137.89		144.81		162.73	
Pseudo R squared	0.3307		0.3583		0.3746	
No. Observations	78,931		78,931		78,931	

Notes: Robust standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively. Solid fuel has been used as the base category for cooking fuel. Model 1 considers only the head's characteristics, Model 2 includes spouse's and other household characteristics, and Model 3 considers all the characteristics as the control variables.

Table 3.5 shows that remittances enhance the use of clean and transitional fuels for cooking in all models, compared to solid fuels. According to our base model (Model 3), a 1% increase in remittances boosts clean fuel use by 0.037 units and transitional fuel use by 0.036 units. These findings reject the second and third null hypotheses (H_{02} and H_{03}), indicating that remittances positively and directly affect clean and transitional fuel choices. The results align with those of earlier studies conducted in various circumstances. For example, Hassan (2020) discovered that a 10% increase in remittance income could improve the likelihood of adopting LPG by 2% for cooking in rural Bangladesh. He stated that high revenue from remittances and increased health awareness make modern energy more affordable. In Morocco, Akçay and Demirtaş (2015) found that short-term and long-term remittances impact about 1% of the variation in energy usage of households, but they did not highlight the impact of remittances on various energy sources or their causes.

3.5.3 Mediation Analysis

One of the objectives of this paper is to identify the mediating role of household wealth in the relationship between remittances and the type of cooking fuel used. Since the treatment (remittance) and the mediator (wealth index) are endogenous, we used an IV Mediate model to identify this mediation effect, and the results are depicted in Table 3.6.

Table 3.6: IV Mediation Results

Pathways	**Direct Effect**	**Indirect Effect**	**Total Effect**
Remittances to Clean Fuels	0.405*** (0.047)		
Remittances to Transitional Fuels	0.107*** (0.014)		
Remittances to Solid Fuels	-0.513*** (0.058)		
Remittances to Wealth Index	1.787*** (0.204)		
Wealth Index to Clean Fuels (*controlled for the treatment*)	0.229*** (0.010)		
Wealth Index to Transitional Fuels (*controlled for the treatment*)	0.060*** (0.006)		
Wealth Index to Solid Fuels (*controlled for the treatment*)	-0.289*** (0.011)		
Remittances to Wealth Index to Clean Fuels	-0.003*** (0.001)	0.409*** (0.050)	0.405*** (0.047)
Remittances to Wealth Index to Trans. Fuels	-0.001 (0.000)	0.108*** (0.016)	0.107*** (0.015)
Remittances to Wealth Index to Solid fuels	0.005*** (0.001)	0.517*** (0.062)	-0.513*** (0.058)

Notes: standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively.

IV Mediate generates the results not only for the mediating effect but also for the direct effect of all the variables in the model. As a result, the findings support the CF estimates, demonstrating the positive association between remittances and clean and transitional fuels while showing the negative association with solid fuels.

Furthermore, the findings indicate that a 1% increase in remittances boosts household wealth by 0.018 units. This reveals that the fourth null hypothesis is also rejected (H_{04}), suggesting a significant positive link between remittances and household wealth. Many pieces of evidence suggest that remittance recipients have more wealth than non-remittance recipients. For example, remittances enable Nigerian (Ajaero et al., 2018; Ajefu, 2018) and Bangladeshi households (Mahapatro, 2016) to acquire and accumulate productive and non-productive goods and increase the asset index. Likewise, various empirical studies found that remittances enhance the wealth of migrant families through their investment in housing (Abainza & Calfat, 2018; Adams & Cuecuecha, 2010), education (Adams & Cuecuecha, 2010; Mahapatro et al., 2017), and health (Mahapatro et al., 2017). This finding also follows the NELM theory, which claims that migration is a family decision to improve socioeconomic conditions and well-being in one's home country (Stark & Bloom, 1985), and this can be realised through increased wealth.

Further, a unit increase in the wealth index increases the clean and transitional fuel usage by 0.229 units and 0.06 units, respectively. As a result, the fifth (H_{05}) and sixth (H_{06}) null hypotheses are rejected, confirming that wealth has a direct, positive effect on clean and transitional fuel consumption. The finding is similar to the results of previous studies in various settings. Rahut et al. (2016) observed that wealthier families in Bhutan use and rely more on clean energy sources such as electricity and LPG. In addition, families in rural China with a higher wellness index consume more modern fuels (Song et al., 2018). This could be related to the fact that wealthier households can afford the extra cost of using modern fuels compared to solid fuels. Furthermore, members of affluent families have greater access to education, and as a result, they are aware of the negative health effects of solid fuel consumption. Therefore, they use more clean and transitional fuels for cooking than the less-wealthy families.

Finally, the wealth index has a positive significant mediating impact (indirect effect) on the relationship between remittances and clean fuel use by rejecting the seventh null hypothesis (H_{07}). This would happen because, as migrant remittances grow, they are more inclined to spend remittances on home improvements. As a result, migrant families are more likely to adopt modern cooking methods and technologies, which ultimately enhance the use of advanced fuels for cooking. Moreover, the wealth index demonstrates a significant mediation effect between remittances and transitional fuel use as well as remittances and solid fuel use. These findings exemplify the study's fundamental contribution, integrating two distinct pieces of literature on remittance and energy through household wealth.

3.5.4 Robustness Check

To check the robustness of the results, we employed the GSEM as it enables multinomial logistic modelling with robust error with clusters. Further, it simultaneously measures the direct, indirect, and total effects when including mediating variable/s (Liu et al., 2020; Pei et al., 2020; Silverstein & Bengtson, 2018). The GSEM results show that an increase in remittances increases clean and transitional fuel use (see Table 3A.3 in Appendix 3A). The GSEM results are consistent with the previous results. However, the impact of remittances on cooking fuel choice becomes substantially stronger after accounting for endogeneity.

3.6 Conclusion and Policy Implications

This research examines the impact of migration and remittances on the usage of cooking fuels using four waves of Sri Lankan Household Income and Expenditure surveys. It also brings together two previously unrelated pieces of literature on remittances and energy through household wealth. According to PSM analysis, migrants are at least 5.7% more likely to use clean fuels for cooking than non-migrants. According to CF analysis, a 1% increase in remittances boosts clean and transitional fuel use by about 0.04 units compared to solid fuels. Furthermore, the IV mediation analysis shows that remittances increase household wealth, which in turn, increases the use of clean cooking fuels, indicating that household wealth has a significant mediating impact on the relationship between migrant remittances and cooking fuel use.

The current study results have significant implications for meeting SDG 7 by 2030. Policymakers can utilize overseas inward migrant remittances as a strategic tool in formulating a financial, legal, and regulatory framework to achieve SDG 7. This can be accomplished through a variety of strategies. First, strengthen the ability of the financial services sector to channel remittances into a variety of sustainable energy technologies, like fuel-efficient cooking appliances. Second, direct remittances towards energy development projects in rural areas, such as electrification and solar power. Third, provide incentives such as lowering the cost of remittance transactions or lowering taxes on modern cooking equipment for migrant families to invest in modern cooking methods and technologies. Furthermore, educational authorities can develop programs to enhance awareness of the negative impacts of using dirty fuels on human health and environmental sustainability, particularly for women who undertake most household chores. These actions will promote clean fuel use and help to achieve SDG 7 as expected.

While this article examines several significant control variables that influence migration and remittances, data restrictions have limited the examination of some factors that may influence cooking fuel choice, such as fuel prices. Therefore, future researchers could look into how fuel prices affect this scenario. Moreover, they might also think about how migrant knowledge, skills, and experience in the destination country influence their decision to use clean fuel for cooking.

3.7 Appendix

Appendix 3A – Tables

Table 3A.1 OLS Regression

Remittance (log)	Model 1	Model 2	Model 3
Average province rainfall times the log of distance to the nearest bank	-0.0001***	-0.0001***	-0.0001***
	(0.000)	(0.000)	(0.000)
First-Stage F Statistic	137.89	144.81	162.73
Number of Observations	78,931	78,931	78,931

Notes: Robust standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively.

Table 3A.2 Test of the Exclusion Restriction

	Lighting Source (Clean = 1)	Access to Electricity (Yes = 1)	Access to Safe Drinking Water (Yes = 1)
First-Stage Regression Average province rainfall times the log of distance to the nearest bank	-207.14***	-159.78***	-237.98***
	(10.29)	(18.54)	(13.94)
Second-Stage Regression Cooking Fuel Use	-0.022	-0.013	0.043
	(0.017)	(0.034)	(0.083)
Wald Test of Exogeneity (Cragg-Donald Wald F)	76.4***	75.02***	75.84***

Notes: Robust standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively. The instrumented variable, remittance, is measured in log remittance. All specifications include a vector of controls that include other household income, heads' characteristics (age, gender, marital status, education, and employment sector), spouses' characteristics (age and education), household size, number of children, number of females, residential sector and district dummys.

Table 3A.3 GSEM Results

Explanatory Variables	Transitional Fuels	Clean Fuels
Migrant Remittances (log)	0.031***	0.043***
	(0.005)	(0.004)

Wealth Index	0.399***	0.602***
	(0.010)	(0.008)
Head's Characteristics		
Gender (Female = 0)	0.040	0.036
	(0.010)	(0.045)
Marital Status (Never Married = 0)	-0.244*	-0.055
	(0.126)	(0.103)
Age (log)	-0.728***	-0.251***
	(0.079)	(0.094)
Primary Education (No Schooling = 0)	-0.017	-0.018
	(0.117)	(0.093)
Secondary Education (No Schooling = 0)	0.210*	0.401***
	(0.118)	(0.093)
Tertiary Education (No Schooling = 0)	-0.858***	1.056***
	(0.144)	(0.120)
Government Sector (Other sectors = 0)	-0.123**	-0.190***
	(0.047)	(0.036)
Private Sector (Other sectors = 0)	-0.218***	-0.299***
	(0.047)	(0.037)
Spouse's Characteristics		
Age (log)	-0.065***	-0.074***
	(0.018)	(0.014)
Primary Education (No Schooling = 0)	-0.145	0.002
	(0.150)	(0.117)
Secondary Education (No Schooling = 0)	-0.186	0.120
	(0.148)	(0.115)
Tertiary Education (No Schooling = 0)	0.365*	0.611***
	(0.172)	(0.141)
Household and Other Characteristics		
Household Size	-0.103***	-0.145***
	(0.016)	(0.012)
Number of Children Under 5	0.206***	0.269***
	(0.036)	(0.028)
Number of Females	-0.040*	-0.008
	(0.022)	(0.017)
Other Household Income	-0.002	0.018**
	(0.012)	(0.011)
Residential Sector		
Urban Sector (Estate = 0)	1.724***	1.693***
	(0.103)	(0.079)
Rural Sector	-0.116	-0.016
(Estate = 0)	(0.099)	(0.078)
District Dummy	Yes	
Year Dummy	Yes	
Log psedolikelihood	-186353.99	
Number of Observations	78,931	

Notes: standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively. Solid fuel has used as the base category for cooking fuel.

Appendix 3B - Principal Component Analysis (PCA)

This study uses PCA to construct the household wealth index based on literature (Chasekwa et al., 2018; Filmer & Pritchett, 2001; Vyas & Kumaranayake, 2006). The PCA is one of the most popular multivariate statistical techniques that exact only the most crucial information from the observed data and develop the set of new orthogonal variables called principal components.

PCA makes uncorrelated components from an initial set (suppose n) of correlated variables, and those components are considered linear weighted components of the initial variables (Vyas & Kumaranayake, 2006). The derivation of principal components from a set of variables X_1 to X_n are as follows:

$$PC_1 = \alpha_{11}X_1 + \alpha_{12}X_2 + \ldots + \alpha_{1n}X_n$$

$$PC_m = \alpha_{m1}X_1 + \alpha_{m2}X_2 + \ldots + \alpha_{mn}X_n$$

where α_{mn} represents the weight for the m^{th} principal component and n^{th} variable, the weight for each component are ordered from 1 to m. The first components (PC_1) shows the largest possible variation in the original data, which is subject to the sum of squared weights ($\alpha^2_{11} + \alpha^2_{12} + \ldots + \alpha^2_{1n}$). The second component is entirely uncorrelated with the first component and shows the additional variation subject to the same constraint. Likewise, each additional component explains the further variation at a decreasing rate. Element is given by the eigenvector of the correlation matrix or covariance matrix. The eigenvalue measures each principal component's variance and indicates the percentage of variances in the total data explained. Fewer components are required if there is a higher degree of correlation among the original variables in the data (Vyas & Kumaranayake, 2006).

Following the rule of thumb, we first select the variables in the data set with a frequency of between 5% and 95% to include in the PCA. Then we looked at the correlation and eliminated any variables with a correlation of less than 1.0 or greater than 0.9. Finally, we use the 12 households' durable assets (ownership of radio, TV, VCD, sewing machine, washing machine, refrigerator, cooker, electric fan, computer, telephone, motor bicycle and car), type of wall, type of roof, the number of bedrooms, and the housing area to measure the household wealth. The sample adequacy is satisfied by the Kaiser-Meyer-Olkin measure value of 0.90 (kmo > 0.6). The wealth index, which has a 4.85 eigenvalue and a cumulative variation of 30.28%, is chosen as the first principal component.

Appendix 3C - Multinomial Logistic Regression Model

The MNL model follows random utility theory (RUT). The RUT states that every individual is a rational decision-maker and selects the best among alternatives to maximize utility (McFadden, 1978). Therefore, a household chooses the primary cooking fuel from various energy sources that yield the highest utility (Mensah & Adu, 2015). For instance, assume that the i^{th} household has three fuel alternatives (solid, transitional and clean fuels), and the household chooses the fuel " j" to maximize the utility in the time period t (t = 1,2,3) with a random effect can be described as follows:

$$V_{ijt} = X_{it}\beta_j + u_i + \varepsilon_{ijt} \quad (18)$$

where X_{it} is a vector of explanatory variables for each household's cooking fuel preference, β_j is a vector of cooking fuel choice-specific coefficients, u_i is an unobserved heterogeneity of household characteristics, and ε_{ijt} is an independently and identically distributed random error term. Thus, the conditional probability that household i chooses cooking fuel j in time t with unobserved household heterogeneity is:

$$\Pr\left(f_{it} = t_j | x_{it}, u_i\right) = \frac{\exp\left(x_{it}\beta_j + u_{ij}\right)}{1 + \sum_{k \neq B}\left(x_{it}\beta_k + u_{ij}\right)}, j \neq B \quad (19)$$

where B denotes the base outcome of the cooking fuel type. The equation shows that the probability of choosing a cooking fuel type is conditional on the set of household-level effects and the observable household characteristics (Choumert-Nkolo et al., 2019).

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Chapter 4: Migrant Remittances, Income Inequality and Energy Poverty: A Pseudo Panel Approach

4.1 Introduction

Energy is a basic need for all living beings and is crucial for sustainable development (Guta, 2018; Mendoza et al., 2019; Nussbaumer et al., 2012). However, about 733 million people worldwide live without electricity, and 2.4 billion people do not have access to clean cooking fuel (IEA, 2022). This reflects widespread energy poverty; the inability to access adequate, affordable, reliable, high-quality, safe, and eco-friendly energy services (Reddy et al., 2000). Energy poverty has severe negative impacts on human health, education, and well-being (Awaworyi Churchill et al., 2020; Zhang et al., 2019). In addition, it accelerates deforestation and emits harmful greenhouse gasses (Chevalier & Ouédraogo, 2009; Sovacool, 2012).

Due to the severe negative repercussions of energy poverty, the United Nations introduced Sustainable Development Goal (SDG) 7, ensuring universal access to affordable, reliable, and modern energy by 2030. Following the formation of SDG 7, there has been a surge in interest and effort to alleviate energy poverty around the world, and it has gained more attention among scholars (Agradi, 2023; Awaworyi Churchill et al., 2020; González-Eguino, 2015; Hosan et al., 2023; Jayasinghe et al., 2021). However, alleviating energy poverty is challenging because it is linked to a variety of factors, including accessibility and affordability of clean energy (Hosan et al., 2023; Igawa & Managi, 2022). Most countries have complete access to clean energy sources such as electricity, Liquefied Petroleum Gas (LPG), natural gas, biogas, and solar, but most face affordability challenges (Agradi, 2023; Bardazzi et al., 2021; Hosan et al., 2023; Igawa & Managi, 2022).

The issue of affordability is directly connected to income; therefore, poorer households in Low and Middle-Income Countries (LMICs) are more likely to experience energy poverty (González-Eguino, 2015; Igawa & Managi, 2022; Nguyen & Nasir, 2021). Providing modern energy services to low-income households remains one of the difficult challenges confronting LMICs (Jayasinghe et al., 2021). To address this issue, most LMICs now rely on migrant remittances as an alternative source of financing for energy services (Hosan et al., 2023). Migrant remittances to LMICs totalled USD 589 billion in 2021, it is a 7.3% increase over the previous year (World Bank, 2021). As a result, remittances would be a vital source of income in mitigating energy poverty. However, only a few studies have been conducted to date to investigate this association (Agradi, 2023; Barkat et al., 2023; Hosan et al., 2023), but their conclusions about the mechanism by which remittances affect energy poverty are unclear.

Despite that, most previous research shows that migrant remittances have a significant impact on income inequality, and income inequality has a substantial impact on energy poverty. Income inequality is the disparity between high and low-income earners, and it has been identified as the major impediment to energy poverty (Bardazzi et al., 2021; Igawa & Managi, 2022; Nguyen & Nasir, 2021). Because low-income households cannot afford the cost of clean energy, they rely on solid fuels such as firewood, biomass, and crop residue, which harms human health, educational quality, and overall social well-being (Awaworyi Churchill et al., 2020; Kose, 2019; Njiru & Letema, 2018). This will further reduce the income of low-income households and widen the income gap between low and high-income earners, resulting in high-income inequality. Many studies have observed that energy poverty increases as income inequality rises (Acheampong et al., 2022; Bardazzi et al., 2021; Galvin, 2019; Galvin & Sunikka-Blank, 2018; Nguyen & Nasir, 2021). Simultaneously, numerous studies have found that migrant remittances reduce income inequality (Acosta et al., 2008; Azizi, 2021; Bang et al., 2016). As a result, this paper integrates two distinct forms of literature: remittances and energy, through income inequality. Accordingly, this study seeks to address four research questions: (1) Do migrant remittances reduce energy poverty? (2) Do migrant remittances reduce income inequality? (3) Does income inequality increase energy poverty? (4) Is income inequality mediating the relationship between migrant remittances and energy poverty?

To answer the above research questions, we used pseudo-panel data from Sri Lanka from 2009 to 2019 and an instrumental variable approach as the estimation technique. We operationalized energy poverty using the Multidimensional Energy Poverty Index (MEPI) and income inequality using the Per Capta Gini Index (PCGI). To answer the first research question, we used the Two-Stage Least Square (2SLS) method, and the results show that remittances significantly reduce energy poverty. To answer the remaining research questions, we used Instrumental Variable (IV) mediation analysis. According to the findings, remittances have an inverse association with income inequality, but income inequality positively correlates with energy poverty. Notably, we discovered that income inequality significantly mediates the relationship between remittances and energy poverty.

To this end, our study has a three-fold contribution to the literature. First, to our best knowledge, this will be the first study examining the impact of migrant remittances on multidimensional energy poverty using pseudo-panel data from over 84,000 households. Most previous studies have only looked at the effects of migration and remittances on poverty in general (Acosta et al., 2008; Adams et al., 2008; Aregbeshola, 2022; Bertoli & Marchetta, 2014). Only very few studies have looked at the effects of remittances on energy poverty, but they either used micro-level data for a single period (Hosan et al., 2023) or macro-level data (Agradi, 2023; Barkat et al., 2023). Notwithstanding, no study has used panel data at the household level to investigate the relationship between remittances and energy poverty. Thus, examining the link between migrant remittances and energy poverty using household-level panel data for a 10-year period is crucial for policymakers in formulating energy policies to achieve SDG 7 by 2030. Second, this will be a pioneering study to employ income inequality as a mediating variable to examine the impact of migrant remittances on energy poverty. The paper's uniqueness stems from integrating two disparate research areas, namely remittances and energy, through income inequality. Income inequality has not received much attention in studies on energy poverty (Galvin, 2019; Galvin & Sunikka-Blank, 2018), suggesting further research on this topic. Therefore, this will help to explain one of the key mechanisms by which remittances affect energy poverty. Finally, this study greatly contributes to the literature by employing an advanced statistical technique, the instrumental variable approach for pseudo-panel data to determine both the direct and mediating effects of the variables involved.

The remainder of this paper is organized as follows. Section 2 briefly explains the literature related to migrant remittances, income inequality, and energy poverty. Section 3 outlines the data and variable description. Section 4 briefly reviews the empirical model. Section 5 reports and discusses the results. Finally, section 6 provides conclusions, and policy implications and suggests avenues for future research.

4.2 Literature Review

This section examines the evidence of the links between migrant remittances, income inequality, and energy poverty. The relationships are then used to develop the study's hypothesis.

4.2.1 The Nexus between Remittances and Income Inequality

Migrant remittances are the financial or in-kind transfers made directly by migrants to their families in their origin countries (IOM, 2019). Remittance flows are a stable source of capital compared to the other kinds of private capital flows (such as exports, FDI, and official aid) because they do not depend on external factors like cyclical fluctuations and external shocks (Koechlin & Leon, 2007). There are three theoretical motivations for sending remittances: (1) altruism, or the desire of migrants to assist family members in their home countries; (2) insurance, or remitting to insure their families against risks and shocks in their homeland; and (3) investment, or remitting either to invest at home or to receive prospective family bequests (Rapoport & Docquier, 2006). Yet, most empirical research reveals that remittances are driven by a combination of altruistic, insurance, and investment motives (Adams, 2011).

Because of these concerns, migrant remittances have the potential to alter the income distribution of remittance-receiving households, thus addressing income inequality. Income inequality is the disparity between high and low-income earners (Nguyen & Nasir, 2021). Many studies have proved that international remittances significantly influence income inequality, but the effect is ambiguous. For example, international remittances worsen income inequality in the home community in rural Egypt (Adams, 1989), Bangladesh (F. Ahmed et al., 2021), Ghana (Adams et al., 2008), Mexico (Taylor et al., 2005) and 20 major remittance-receiving countries (Song et al., 2021). On the other hand, international remittances reduce income inequality in Nicaragua (Barham & Boucher, 1998), Latin America (Acosta et al., 2008), Kenya (Bang et al., 2016), Indonesia (Adams & Cuecuecha, 2010) and 103 developing countries (Azizi, 2021). In addition, some found remittances have no significant impact on income inequality (Adams & Mahmood, 1992; Deluna & Pedida, 2014; Sulemana et al., 2019).

The reason for the ambiguous impact of remittances on income inequality is that inequality will increase if remittances are skewed in favour of high-income households (Azizi, 2021) and income inequality will decrease if remittances are skewed in favour of low and middle-income households (Agwu et al., 2018). As our study context is related to LMICs, we hypothesise that remittances reduce income inequality.

Hypothesis 1. There is a negative relationship between migrant remittances and income inequality.

4.2.2 The Nexus between Income Inequality and Energy Poverty

There is no generally accepted definition for energy poverty, but simply it is the inability to access adequate, affordable, reliable, high-quality, safe, and eco-friendly energy services (Reddy et al., 2000). Income inequality is one of the major impediments to ending energy poverty (Igawa & Managi, 2022; Nguyen & Nasir, 2021). Nguyen and Nasir (2021) observed that higher income inequality worsens energy poverty using a sample of 51 countries. Furthermore, Bardazzi et al. (2021) found a positive association between income inequality and energy poverty among households living in the Italian region.

Income inequality may hinder efforts to combat energy poverty due to the high cost of energy (Acheampong et al., 2022). For instance, as income inequality increases, poorer households use less clean energy because they have fewer financial resources to enhance their energy capabilities (UNDP, 2019). Moreover, higher income inequality leads to greater energy poverty because poorer households are forced to live in thermally inefficient homes due to a lack of money to pay for heat and electricity (Galvin, 2019). In the majority of energy-poor nations, the poorest pay a disproportionate portion of their earnings for energy because of the higher initial cost of energy-efficient equipment (UNDP, 2019). According to Galvin and Sunikka-Blank (2018) income inequality not only exacerbates energy poverty by increasing the number of poor households, but it can also distort energy markets, making it more difficult for the poor to access energy services such as reducing access to electricity. As a result, we propose the following hypothesis:

Hypothesis 2. There is a positive relationship between income inequality and energy poverty.

4.2.3 The Nexus between Remittances and Energy Poverty

Remittance income is an alternative financing source that can be utilized for energy services (Hosan et al., 2023), and it affects clean energy consumption in two ways. On the one side, remittances increase the purchasing power of remittance-receiving households to pay for the costs of energy use and uptake, such as energy bills, renewables, and energy-efficient solutions (Agradi, 2023). Remittances improve access to electricity by providing enough income to connect the national electricity network (Djeunankan et al., 2023). Furthermore, Scott et al. (2018) also observed that migration can help to improve access to affordable energy services by boosting migrants' incomes through remittances. Moreover, in Bangladesh, Hassan (2020) examined that rainfall-driven remittances reduce the probability of using dirty fuels such as animal dung and fuel wood while increasing the use of cleaner fuels such as LPG as access to affordable energy improves. Theoretically, this may occur due the altruistic motives in which migrants send remittances to support their family members in unfavourable economic circumstances.

Remittance income, on the other side, is used to develop infrastructure and technologies for various types of clean fuel (Mendelson, 2013). For instance, the 3x1 Migrant Program in Mexico directs remittances to invest in local development, such as electrification projects (Orozco & Lapointe, 2004). In Ecuador, a clean energy technology programme has been coupled with a financial remittance mechanism to boost rural energy access (IFAD, 2009). In the case of Bangladesh, remittance income significantly contributes to rural households adopting solar home systems as a source of energy (Murphy & Sharma, 2014). As a result, remittance income has a significant impact to reduce multidimensional energy poverty (Hosan et al., 2023). Accordingly, remittance income represents a potential stimulus in providing support to households to utilize clean energy. Therefore, we hypothesize that remittances may have a positive influence on reducing energy poverty.

Hypothesis 3. Migrant remittances reduce energy poverty.

Following the preceding literature, we assume that migrant remittances have a greater probability of reducing income inequality and income inequality has a higher probability of increasing energy poverty. Accordingly, we propose the following hypothesis:

Hypothesis 4**.** Income inequality mediates the relationship between migrant remittances and energy poverty.

4.3 Data and Variable Description

Sri Lanka offers an appealing backdrop to examine energy concerns and their connection to migrant remittances for a variety of reasons. In terms of remittances, worker remittances are one of the largest foreign exchange earnings in Sri Lanka, accounting for more than 8% of the Gross Domestic Product (GDP) from 2012 to 2020. Remittance income amounts to US$ 7015.4, 6717.2, and 7103.9 million, in 2018, 2019, and 2020, respectively. Despite the covid in 2021, it totalled US$ 5419.5, accounting for about 6.18% of Sri Lanka's GDP (CBSL, 2021).

In terms of energy, although Sri Lanka attained universal access to electricity in 2019, still 69% of Sri Lankans are lack access to clean fuel for cooking (United Nations, 2020). As a result, the country faces significant development challenges in providing affordable, accessible, and reliable energy services. Furthermore, energy poverty is an unexplained concept in Sri Lanka. Therefore, the measurements, discussions, and research on energy poverty are largely missing in the policy and public domain in Sri Lanka, suggesting further investigations (Jayasinghe et al., 2021). Thus, we select Sri Lanka as the study context to examine the effect of migrant remittances on energy poverty at the micro-level.

4.3.1 Data Description

This study uses repeated cross-sectional data for four waves (2009, 2012, 2016 and 2019) of Household Income and Expenditure Surveys (HIESs). The Department of Census and Statistics in Sri Lanka conducts HIES every three years, which provides essential socioeconomic data on demographics, income, expenditure, school education, health, and household assets.

The survey's sample design is divided into two stages, with each district's urban, rural, and estate sectors serving as stratification domains. At the primary stage of the survey, 2500 primary sampling units were chosen from the sampling frame. Then, ten housing units were selected for the survey from each primary sampling unit. The total sample size was 99522 households, which included 23641, 25319, 25640 and 24922 dwelling units in 2009, 2012, 2016 and 2019, respectively. Finally, after removing the rows with missing values for variables relevant to the study, we ended up with 84 483 households for analysis. This includes 19871 households in 2009, 20378 households in 2012, 24406 households in 2016, and 19828 households in 2019.

4.3.2 Variable Description

The main objective of this study is to examine the effect of migrant remittances on household energy poverty. Thus, the dependent variable is energy poverty. Energy poverty measurement has evolved from one-dimensional to multidimensional approaches. For example, the energy poverty line (Foster et al., 2000), per capita energy consumption (Goldemberg & Johansson, 1995), and energy budget shares (Awaworyi Churchill & Smyth, 2020; Awaworyi Churchill et al., 2020) are included in the one-dimensional approaches to energy poverty. Although they are straightforward, they only provide insights into a single measurement of energy poverty and do not sufficiently capture most of the variations in energy consumption patterns of different demographic groups (Nussbaumer et al., 2012; Pachauri et al., 2004). On the other hand, composite indices like the Energy Development Index (EDI), Multidimensional Energy Poverty Index (MEPI), Energy Poverty Index (EPI), and Compound Energy Poverty Index (CEPI) capture the multidimensional nature of energy poverty into a single number.

We employed MEPI to measure energy poverty because it is an excellent multidimensional approach to measuring energy poverty at the household level (Abbas et al., 2020; Crentsil et al., 2019; Jayasinghe et al., 2021; Mendoza et al., 2019; Nussbaumer et al., 2012). MEPI captures the incidence and intensity of energy poverty as well as focuses on the deprivation of access to modern energy services. The MEPI is computed using six key indicators representing energy dimensions: cooking, lighting, refrigeration, entertainment/education, communication, and space cooling (see Table 1). These indicators encompass common energy services demanded by households and hence enable them to capture the deprivation of the services or convenience of the households in terms of both accessibility and affordability. We also include telecommunication as an additional indicator because the latest figures highlight the importance of phones and computers in socioeconomic development (Jayasinghe et al., 2021). However, because the Sri Lankan HIES does not provide data on indoor air pollution (whether the household cooks on the stoves or an open fire with biomass fuel in an enclosed area), it was excluded from the dimension of cooking.

Most research has employed normative weights to construct the MEPI, although value judgments on trade-offs between dimensions are not based on the distributional achievements in the society under discussion (Decancq & Lugo, 2013). Nussbaumer et al. (2012) also emphasize that the arbitrary weights used in their study are only for demonstration purposes and can be adjusted for the specific analysis. Therefore, we used weights generated through the Principal Component Analysis (PCA), following Jayasinghe et al. (2021). The PCA is a data-driven method for transforming MEPI indicators into new (uncorrelated) components, with the produced principal component serving as a weight for the set of indicators. The assigned weights are given in the last column of Table 4.1.

Table 4.1: Description of MEPI dimensions

Dimension	Indicators	Deprivation cut-off	PCA weights
Cooking	Modern cooking fuels	Any fuel used besides electricity, kerosene, natural gas, or biogas	0.32
Lighting	Electricity access	Has no access to electricity	0.12
Refrigeration	Ownership of household service appliance	Do not own a refrigerator	0.08

Entertainment/ Education	Ownership of entertainment/education appliances	Do not own a radio Do not own a television	0.11 0.11
Communication	Ownership of telecommunication means	Do not own a landline Do not own a mobile Do not own a computer	0.07 0.07 0.05
Space cooling	Ownership of household cooling appliance	Do not own an electric fan	0.07

A household is defined as energy poor if the combination of the above deprivations exceeds a predefined threshold, and based on the literature, we use 0.33 as the threshold (Alkire & Foster, 2011; Jayasinghe et al., 2021; Nussbaumer et al., 2012).

The independent variable of the study is migrant remittances. To have better-behaved data distributions, we use the natural logarithm (log) of remittances to validate normality. Notably, remittances are endogenous, (Adams & Cuecuecha, 2010, 2013; Vadean et al., 2019), and thus, we use *average province rainfall multiplied by the log of distance to the nearest bank* as the instrumental variable to address the endogeneity (more detail are given in section 4.2).

More importantly, one of the major focuses of this study is to examine whether income inequality mediates the association between remittances and energy poverty. To quantify the mediating variable, income inequality, we primarily use the Gini index because it is a good measure of income inequality and it is widely used in literature (Adams & Cuecuecha, 2010; Azizi, 2021; Bardazzi et al., 2021; Barham & Boucher, 1998; Kimhi, 2010; Nguyen & Nasir, 2021). The Gini index measures how far an economy's income distribution deviates from a perfectly equal distribution among individuals or households (World Bank, 2022). A Gini coefficient ranges from 0 to 1, with 0 indicating perfect equality and 1 indicating the highest inequality (Xie & Zhou, 2014). We adjusted the Gini index to the household size[30] due to two reasons. First, household size has a significant impact on end-use energy consumption and thus on energy poverty (Pachauri et al., 2004). Many studies have found that a household with more members has a higher demand for fuels, thus, they tend to choose unsafe and low-quality fuels to keep their monetary burden low (Acharya & Adhikari, 2021; Paudel et al., 2018; Sharma et al., 2019; Sharma et al., 2020). On the other hand, household size is a significant factor in determining income inequality (Beblo & Knaus, 2001; Xie & Zhou, 2014). Therefore, to remove the confounding effect of family size, and to get a measure of the variation of Gini at

[30] Household size refers to the number of persons usually living in the household, including boarders and servants (Census & Statistics Department, 2012)

the household level, we divide the Gini index by household size and calculated the Per Capita Gini Index (PCGI) to measure income inequality. In addition, we use the Palma ratio (adjusted to the household size) as a proxy for income inequality to check the robustness of the results. It is the ratio of national income shares of the top 10% of households to the bottom 40% (Cobham & Sumner, 2014).

Following the literature, this study employs many control variables that affect energy poverty. We begin with other household income, which is the sum of employment, agricultural, non-agricultural, and other incomes (remittances from migrants are not included). Energy poverty is inversely related to household income because fuel affordability is directly related to income (Hosan et al., 2023; Igawa & Managi, 2022). We also included head and spouse demographic characteristics such as age, gender, marital status, education, and employment sector because they are vital determinants of energy choice (Acharya & Marhold, 2019; Rahut et al., 2016). In addition, household characteristics such as household size (Sharma et al., 2020), the number of children under the age of five and the number of females (Behera et al., 2015), included as these factors significantly influence energy poverty. We also constructed a wealth index using Principal Component Analysis (PCA) and it is added as a control variable (Rahut et al., 2016; Song et al., 2018). Finally, we included the residential sector (urban, rural, and estate sectors[31]). The descriptive statistics are reported in Table 4.2.

Table 4.2: Descriptive Statistics

Variable	2009		2012		2016		2019		Overall	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MEPI	0.534	0.157	0.493	0.206	0.471	0.202	0.431	0.207	0.482	0.198
Migrant Remittances	9891	64571	13618	102023	20270	126570	25121	157154	17363	118103
Per Capta Gini Index	0.208	0.125	0.195	0.118	0.191	0.117	0.197	0.042	0.197	0.120
Per Capta Palma Ratio	3.536	2.124	2.401	1.459	2.413	1.475	2.127	1.319	2.607	1.700
Other Household Income	93767	1547105	100218	372155	185891	468760	149206	854999	134948	912627
Wealth Index Quintile	2.999	1.414	2.999	1.414	3	1.414	3.001	1.414	3	1.414
Head Age	50.68	13.911	50.90	13.908	52.70	14.192	54.21	14.02	52.14	14.086
Head Education	8.696	4.126	8.826	3.971	8.891	3.866	9.093	3.756	8.877	3.932
Spouse Age	44.8	12.42	45.32	12.69	47.28	12.69	48.52	12.61	46.52	12.70
Spouse	6.619	5.326	6.797	5.352	6.610	5.317	7.498	5.034	6.866	5.275

[31] Estate sector consists of all plantations which are 20 acres or more in extent and ten or more resident labourers Census and Statistics Department. (2012). *Census and Statistics Survey* (978 – 955 – 577 – 940 – 1). http://203.94.94.89/mainsite/Population/StaticalInformation/CPH2011/CensusPopulationHousing2012-FinalReport

Education										
Household Size	4.338	1.806	4.194	1.749	4.201	1.697	4.026	1.642	4.190	1.727
Children Number	0.252	0.518	0.285	0.565	0.237	0.517	0.182	0.456	0.239	0.517
Female Number	2.224	1.202	2.174	1.190	2.193	1.180	2.057	1.088	2.164	1.169
	Prop.	**SE**	**Prop.**	**SE**	**Prop.**	**SE**	**Prop.**	**SE**	**Prop.**	**SE**
Head Male	0.760	0.003	0.763	0.003	0.738	0.003	0.746	0.003	0.751	0.001
Head Married	0.978	0.001	0.979	0.003	0.980	0.001	0.953	0.002	0.973	0.001
Head Government Employee	0.108	0.002	0.103	0.002	0.087	0.002	0.084	0.002	0.095	0.001
Head Private Employee	0.313	0.003	0.322	0.003	0.300	0.002	0.298	0.003	0.308	0.002
Head Other Employee	0.578	0.004	0.575	0.003	0.613	0.003	0.618	0.003	0.596	0.002
Urban Sector	0.265	0.003	0.253	0.003	0.151	0.002	0.161	0.003	0.205	0.001
Rural Sector	0.648	0.003	0.658	0.003	0.807	0.003	0.98	0.003	0.731	0.002
Estate Sector	0.087	0.002	0.089	0.002	0.041	0.001	0.042	0.001	0.064	0.001
No.Obs.	19, 871		20, 378		24, 406		19, 828		84, 483	

According to Table 4.2, the average MEPI is gradually decreasing from 2009 to 2019 and the mean MEPI is 0.482, indicating that Sri Lankan households are experiencing moderate levels of energy poverty, but the proportion is skewed more towards the energy poor. The average migrant remittance is increasing within the decade and the average is SL Rs.17363[32] (US$ 50, converted to US$1 = SL Rs.350). The average wealth quintile is 3, indicating that most families are middle-income. The head and spouse have an average age of 52 and 47 years, respectively. The average head has a grade 9 education, while the spouse has a grade 7 education. The average household has four members, and two of them are women. As per the proportion estimates, 76% of household heads are males and 98% are married. Furthermore, 30.8% and 9.5% of the head are working in the private and government sector, respectively. 73% of the families are located in rural areas, 20.5% of the families are located in urban areas, and only 6.4% of households are living in the estate sector.

4.4 Empirical Estimation

4.4.1 Pseudo Panel Approach

We examine the relationships between remittances, income inequality, and energy poverty using repeated cross-sectional data from Sri Lankan HIESs conducted in 2009, 2012, 2016, and 2019. However, unlike panel data, cross-sectional data has a significant limitation because

[32] We noticed that the standard deviation of remittances is very high, which is due to increase the number of migrants over the years and various government programmes to channel remittances, such as low transition fees.

it does not have data on the same individual or household over time to be included in the model (Verbeek, 2008). To overcome this issue, Deaton (1985) suggests using the pseudo-panel technique, which allows repeated cross-sectional data to be used at the aggregate level as panel estimation. As a result, the pseudo-panel approach can be used to analyse cross-sectional data as an alternative method to panel data.

In the pseudo-panel approach, individuals are divided into the so-called *cohorts* based on the same permanent observable characteristics of individuals. Therefore, each cohort is made up of a homogeneous group of individuals who are assumed to share the same time-invariant characteristics from one cross-sectional survey to the next (Deaton, 1985; Verbeek, 2008). We chose birth year as the cohort variable in our analysis because it is the most common cohort variable used in empirical studies (Kim & Kang, 2014; Tsai et al., 2014). We formed the cohort by dividing the birth year into seven age groups in order to minimize measurement errors. Following that, the observations are presented by the mean values of the variables in each cohort. A pseudo-panel approach is an effective method for mitigating measurement error-related issues because it uses the mean of the individuals within cohorts rather than individual data. Accordingly, Equation 4.1 shows the estimation of our baseline model, Ordinary Least Square (OLS) regression.

$$\overline{EP}_{ct} = \alpha_0 + \beta_1 \overline{Rem}_{ct} + \beta_2 \overline{II}_{ct} + \beta_3 \overline{X}_{ct} + \varepsilon_{ct} \quad (4.1)$$

where *c* denoted cohort (c = 1,. ., c), and *t* denotes year. $\overline{EP}$ is the mean of energy poverty, $\overline{Rem}$ is the logarithm of average migrant remittances, $\overline{II}$ is the mean of income inequality, X is the vector of household head, spouse and other characteristics that are potentially associated with *EP*, and all are shown as an average. ε_{ij} is the error term, which is assumed to be independent and normally distributed, α_0 is the intercept, and β_1, β_2, and β_3 are the parameters to be estimated.

However, the coefficients of the OLS model produce inconsistent and unbiased estimates in the presence of endogeneity in remittances (Oum et al., 2022; Piracha et al., 2013). Remittances may be endogenous to energy poverty for three reasons (Azizi, 2021; Koomson & Danquah, 2021). First, there is a reverse causality between migrant remittances and energy poverty. For example, energy poverty may cause migrants to send more remittances to alleviate energy poverty in their origin country (for example, invest in modern cooking fuels and technologies), and in return, remittances may be affected by energy poverty due to liquidity constraints. Second, there is a measurement error in remittances since official remittances do not cover remittances transferred through informal channels such as *Hawala* or *Undiyal* operators. Last, the presence of unobserved factors in the error term may be linked to both the decision to send remittances and the probability of living in energy poverty. Therefore, we use an instrumental variable approach to address the endogeneity of remittances.

4.4.2 Two-Stage Least Square Method (2SLS)

We address the issue of endogeneity using an Instrumental Variable (IV) approach because it is a common strategy for dealing with endogeneity problems. In linear models, the 2SLS approach is more prominent as an estimation method of IV. Several studies recommended using the 2SLS model to instrument remittances in the first stage and then substituting the fitted remittance values in the second stage (Bayangos & Jansen, 2011; Issahaku et al., 2017; Moniruzzaman, 2020). To employ the 2SLS, we first converted our baseline Equation 1 into a reduced form equation in respect of remittances (one that includes all exogenous variables), as follows.

$$\overline{lnRem}_{it} = \beta_{0+} \beta_1 \overline{CW}_{it} + \beta_2 \bar{C}_{it} + \mu_{it} \quad (4.2)$$

where $\overline{lnRem}_{it}$ denoted log of average migrant remittances received by household *i* at year *t*, $\overline{CW}_{it}$ is the mean of the instrumental variable, $\bar{C}_{it}$ is the average of a set of control variables and μ_{it} is the error term.

The choice of an appropriate instrument that satisfies both instrument relevance and exclusion restriction criteria is crucially essential to address the endogeneity of remittances. Regarding this, the choice of an instrumental variable differs across various studies. Some important studies have employed *monthly rainfall data* as the instrumental variable to address the endogeneity of remittances (Akobeng, 2022; Yang & Choi, 2007). The rationale behind this instrument is that rainfall is a critical factor determining the yield of rain-fed crop that generates the main source of household income from agriculture in countries characterised by a subtropical monsoon climate. It, therefore, is a good predictor of remittances which respond to the income shocks to the household (Yang & Choi, 2007). In addition, many studies have employed *distances* such as *the distance to the railway station* (Adams & Cuecuecha, 2010, 2013; Ambrosius & Cuecuecha, 2016), or *the distance to the city* (Demirgüç-Kunt et al., 2011) as the instrument depending on the study context and the data availability.

A study conducted by Hassan (2020) in Bangladesh used rainfall interaction with cyclone-affected migrant households' distance to the local weather stations as an instrument to address the endogeneity of remittances. Following that, we multiplied the *average province rainfall from the log of distance to the nearest bank* and used it as the instrument. Many studies have used distance to the nearest bank as the instrument to examine the association between financial inclusion and energy poverty (Awaworyi Churchill et al., 2020; Koomson & Danquah, 2021; Koomson et al., 2020). Therefore, we used the distance to the nearest bank as a part of constructing instrumental variable because most migrant families are financially inclusive, with bank accounts and access to banking to perform routine banking operations such as withdrawing cash from remittance receipts. Furthermore, due to the rapid expansion of global money transfer infrastructure and lesser restrictions, most remittances are now channelled through official banking sources (J. Ahmed et al., 2021; Guermond, 2022). Thus, it is reasonable that migrant households will be relocating closer to a bank to lower the transaction costs of frequent visits to a bank or other financial institutions. As a result, we predict that the log of remittances and the distance to the nearest bank will have a negative first-stage relationship.

The instrument, *average province rainfall times the log of distance to the nearest bank*, satisfies the two conditions of a valid instrument: relevance and exogeneity (Stock & Watson, 2007; Wooldridge, 2015). The first criterion of relevance is satisfied (see Table 4A.01 in the Appendix) because the first stage F statistics is exceeding the rule-of-thumb value of 10 (Stock & Yogo, 2005). It suggests that instrument can affect the endogenous variable (log of remittances) without necessarily being correlated with the unobserved factors that influence the outcome variable (energy poverty).

To test the second criterion, exogeneity or exclusion restriction we use the test of over-identifying restrictions following Stock and Watson (2007). For that, we used two instruments, car ownership and lighting source multiplied by the average province rainfall times the log of distance to the nearest bank. We used car ownership and clean lighting (electricity and LPG) as instrumental variables because having a car and a clean lighting source indicates that a household has more assets and wealth. As a result, they are less likely to require remittances for altruism, insurance and investment purposes than lower-wealth families (Bang et al., 2016). Thus, having a car and clean lighting source may significantly influence the amount of remittances sent by migrant workers. A study conducted by Bang et al. (2016) used agricultural land ownership and cell phone ownership to address the endogeneity of remittances in Kenya. Thereafter, we computed three different 2SLS estimators and the results show that the Hansen J statistic is greater than 0.1 satisfying the exclusion restriction condition (see Table 4A.02 in Appendix).

4.4.3 Instrumental Variable Mediation Model (IV Mediation)

One of the primary objectives of this study is to determine the mediating effect of income inequality on the association between migrant remittances and energy poverty. We observed that remittances and income inequality (measured by the per capita Gini index and per capita Palma ratio) are endogenous variables using the endogeneity test. Since both the treatment variable and the mediators are endogenous, a single instrumental variable is sufficient to determine the causal and mediation effect (Dippel, 2017; Joffe et al., 2008). Accordingly, we employ the IV mediation analysis (Dippel et al., 2020; Dippel et al., 2019) with a single instrument.

First, we define the linear equations for remittances (Equation 4.4), income inequality (Equation 4.5) and energy poverty (Equation 4.6) as follows:

$$RDB = \varepsilon_{RDB} \ , \tag{4.3}$$

$$lnRem = \beta_{lnRem}^{RDB}.RDB + \varepsilon_{lnRem} \ , \tag{4.4}$$

$$II = \beta_{II}^{lnRem}.lnRem + \varepsilon_{II} \ , \tag{4.5}$$

$$EP = \beta_{EP}^{lnRem}.lnRem + \beta_{EP}^{II}.II + \varepsilon_{EP} \ , \tag{4.6}$$

where RDB is the instrumental variable (average province rainfall data multiplied by the log of distance to the nearest bank), $lnRem$ is the log of migrant remittances (treatment), II is income inequality (mediator), EP is energy poverty (outcome) and $\varepsilon_{RDB}, \varepsilon_{lnRem}, \varepsilon_{II}, \varepsilon_{EP}$ are error terms, respectively. We assume ε_{RDB} is statistically independent of ε_{lnRem}, ε_{II} and ε_{EP}.

The direct effect of remittances on energy poverty is given by the coefficient β_{EP}^{lnRem}, the indirect effect of remittances to energy poverty is given by the coefficient multiplication $\beta_{EP}^{II}.\beta_{II}^{lnRem}$, a total effect is the sum of these two terms $\beta_{EP}^{lnRem} + \beta_{EP}^{II}.\beta_{II}^{lnRem}$. To identify the linear coefficients $\beta_{lnRem}^{RDB}, \beta_{II}^{lnRem}, \beta_{EP}^{lnem}, and\ \beta_{EP}^{II}$ we use the covariance matrix expressed as $X = \psi \times X + \varepsilon$ in Equation (4.7):

$$\begin{bmatrix} RDB \\ lnRem \\ II \\ EP \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ \beta_{lnRem}^{RDB} & 0 & 0 & 0 \\ 0 & \beta_{II}^{lnRem} & 0 & 0 \\ 0 & \beta_{EP}^{lnRem} & \beta_{EP}^{II} & 0 \end{bmatrix} \times \begin{bmatrix} RDB \\ lnRem \\ II \\ EP \end{bmatrix} + \begin{bmatrix} \varepsilon_{RDB} \\ \varepsilon_{lnRem} \\ \varepsilon_{II} \\ \varepsilon_{EP} \end{bmatrix} \quad (4.7)$$

Equation (4.8) shows the covariance matrix Σ_X of observed variables X:

$$\Sigma_X = \mathrm{Var}\begin{pmatrix} RDB \\ lnRem \\ II \\ EP \end{pmatrix} = \begin{bmatrix} \sigma_{RDBRDB} & \sigma_{RDBlnRem} & \sigma_{RDBII} & \sigma_{RDBEP} \\ \cdot & \sigma_{lnRemlnRem} & \sigma_{lnRemII} & \sigma_{lnRemEP} \\ \cdot & \cdot & \sigma_{IIII} & \sigma_{IIEP} \\ \cdot & \cdot & \cdot & \sigma_{EPEP} \end{bmatrix} \quad (4.8)$$

As ε_{RDB} is statistically independent of ε_{lnRem} , ε_{II} and ε_{EP} , we denote the Σ_ε as follows:

$$\Sigma_\varepsilon = \mathrm{Var}\begin{pmatrix} \varepsilon_{RDB} \\ \varepsilon_{lnRem} \\ \varepsilon_{II} \\ \varepsilon_{EP} \end{pmatrix} = \begin{bmatrix} \sigma_{\varepsilon RDB}^2 & 0 & 0 & 0 \\ \cdot & \sigma_{\varepsilon lnRem}^2 & \rho_{lnRemII}\sigma_{\varepsilon lnRem}\sigma_{\varepsilon II} & \rho_{lnRemEP}\sigma_{\varepsilon lnRem}\sigma_{\varepsilon EP} \\ \cdot & \cdot & \sigma_{\varepsilon II}^2 & \rho_{IIEP}\sigma_{\varepsilon II}\sigma_{\varepsilon EP} \\ \cdot & \cdot & \cdot & \sigma_{\varepsilon EP}^2 \end{bmatrix} \quad (4.9)$$

The variances are denoted by $\sigma_{\varepsilon RDB}^2$, $\sigma_{\varepsilon lnRem,}^2$ $\sigma_{\varepsilon II}^2$, and $\sigma_{\varepsilon EP}^2$. $\rho_{lnRemII}$ is correlation between ε_{lnRem} and ε_{II} , $\rho_{lnRemEP}$ is correlation between ε_{lnRem} and ε_{EP} , and ρ_{IIEP} is correlation between ε_{II} and ε_{EP} . We assume that each variable has zero means.

In a regression of EP on $lnRem$, $lnRem$ is endogenous, but endogeneity cannot arise from confounders that jointly influence $lnRem$ and EP. Endogeneity can only be caused by variables that affect $lnRem$ and II jointly.

4.5 Results and Discussion

4.5.1 Effects of Remittances on Energy Poverty

The primary focus of this study is to examine the effect of migrant remittances on energy poverty. We employ the 2SLS model to identify this association, as the migrant remittances are endogenous. We defined the three models and Table 4.3 shows the second-stage results of the 2SLS analysis.

Table 4.3: 2SLS Results

Variables	Model (1)	Model (2)	Model (3)
Migrant Remittances (log)	-1.282*** (0.227)	-0.177*** (0.017)	-0.424*** (0.015)
Heads' Characteristics			
Gender	1.430*** (0.112)		-1.399*** (0.091)
Age (log)	0.207 (0.208)		2.460*** (0.202)
Marital Status	-0.404*** (0.099)		-0.601*** (0.026)
Education	0.176*** (0.030)		
Primary Education			-0.247*** (0.075)
Secondary Education			-1.235** (0.061)
Tertiary Education			-3.714*** (0.159)
Employment Sector - Government	-0.017 (0.053)		1.168*** (0.066)
Employment Sector - Private	0.616*** (0.049)		1.570*** (0.102)
Spouses' Characteristics			
Age (log)		-0.156*** (0.014)	-0.006 (0.021)
Education		0.018*** (0.004)	
Primary Education			-1.049*** (0.085)
Secondary Education			-2.105*** (0.072)
Tertiary Education			-4.135*** (0.304)
Economic Characteristics			
Other Household Income (log)	0.069*** (0.006)		-0.433*** (0.019)
Wealth Index	-0.499*** (0.117)		-0.252*** (0.010)
Household Characteristics			
Household Size		0.274*** (0.013)	-0.243*** (0.020)
Number of Children		0.103*** (0.009)	0.129*** (0.012)
Number of Females		-0.323*** (0.022)	0.583*** (0.046)

Other Characteristics			
Residential Sector - Urban			1.508*** (0.198)
Residential Sector - Rural			2.460*** (0.187)
First Stage F Statistic	30.84	118.19	432.57
LM Statistic	32.79***	91.07***	63.14***
Endogeneity Test	22.16***	83.56***	73.04***
No. of Observations	84483	84483	84483

Notes: Robust standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively. We use heads, spouse and other characteristics as the control variables. Model 1 includes only the characteristics of the heads, Model 2 includes spouses and other characteristics, and Model 3 considers all characteristics.

In all the Models, an increase in migrant remittances decrease the MEPI. According to our base model (Model 3), a 10% increase in remittances reduce the MEPI by about 0.042 units. The finding rejects the third null hypothesis suggesting that migrant remittances reduce energy poverty. This finding is in line with the literature; in Bangladesh, Hosan et al. (2023) also found that households with remittance income have a significantly lower level of multidimensional energy poverty. The same results were found in 51 African countries (Agradi, 2023), and 76 developing countries (Djeunankan et al., 2023). Theoretically, an increase in migrant remittances alleviates energy poverty in two ways (Hanna & Oliva, 2015). First, an increase in remittances raises household income and affordability. As a result, solid fuels have become inferior goods, while modern fuels have remained normal. Therefore, the substitution effect towards modern fuels can outweigh the wealth effect due to greater household well-being. Second, because remittances are typically used to improve human capital, recipients are more concerned about protecting their health capital (Hassan, 2020). The increased awareness of the negative health consequences of dirty fuel use will strengthen the substitution effect of modern, eco-friendly fuels. In general, the source of income has no impact on the magnitude of the substitution effect. However, increases in household income from specific sources, such as migrant remittances, may affect the substitution effect in some cases. From this end, remittances can use to relieve energy poverty at the household level. This novel phenomenon will have a significant impact on the field of energy research.

Furthermore, all the control variables have the expected sign for energy poverty. For example, increasing the level of education of both the head and spouse gradually reduces energy poverty. This could happen as education level raises awareness of the negative effects on health and education, cause to reduce the use of dirty fuels (Sharma et al., 2020). Higher levels of education, on the other hand, can increase household income and thus improve the affordability of clean fuels (Baiyegunhi & Hassan, 2014). Furthermore, an increase in the number of children under the age of five increases energy poverty because having more children means more child labour to collect fuelwood, which increase the use of dirty fuel.

4.5.2 Mediation Analysis

We use Instrumental Variable (IV) mediation analysis to determine the mediating effect of income inequality on the relationship between migrant remittances and energy poverty. Since both the treatment variable and the mediator variable are endogenous, we use a single instrumental variable, *average province rainfall times the log of distance to the nearest bank,* which was used for 2SLS analysis. The results are given in Table 4.4.

Table 4.4: IV Mediation Analysis

Pathways	**Direct Effect**	**Indirect Effect**	**Total Effect**
Remittances to MEPI	-0.686*** (0.009)		
Remittances to Per Capita Gini Index	-0.216*** (0.003)		
Per Capta Gini Index to MEPI (Controlling for the treatment)	3.176*** (0.015)		
Remittances to Per Capita Gini Index to MEPI	-0.002*** (0.001)	-0.684*** (0.009)	-0.686*** (0.009)

Notes: standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively.

IV Mediate generates the results not only for the mediating effect but also for the direct effect of all the variables in the model with mediation and without mediation. As a result, the findings support the 2SLS estimates, demonstrating that a 10% increase in remittances reduces energy poverty by 0.069 units by rejecting the thrd null hypothesis.

Our first null hypothesis is that remittances decrease income inequality and for that, we use PCGI to operationalize the income inequality. The results show that a 10% increase in remittances decreases the PCGI by 0.022 units, rejecting the furst null hypothesis. It suggests that remittances aid in the reduction of income disparities. Similar findings were reported in many studies (Acosta et al., 2008; Azizi, 2021; Bang et al., 2016; Barham & Boucher, 1998; Chiwuzulum Odozi et al., 2010). This result contradicts the findings of some studies (Adams

& Cuecuecha, 2010; F. Ahmed et al., 2021; Anyanwu & Erhijakpor, 2010; Song et al., 2021). The reason for the ambiguous impact of remittances on income inequality is that inequality will increase if remittances are skewed in favour of high-income households (Azizi, 2021) while inequality will decrease if remittances are skewed in favour of poor and middle-income households (Agwu et al., 2018).

Next, we test the direct effect of income inequality on energy poverty. The results show that a unit increase in PCGI increases the MEPI by 3.176 units. Thus, we can reject the second null hypothesis and conclude that income inequality increases energy poverty. The results are in line with the findings of many studies (Acheampong et al., 2022; Bardazzi et al., 2021; Galvin, 2019; Galvin & Sunikka-Blank, 2018; Nguyen & Nasir, 2021). According to Galvin (2019), income inequality worsens energy poverty in two ways. First, the high cost of clean energy makes it unaffordable for low-income families. Second, income inequality distorts energy markets, making it more difficult for the poor to access clean energy sources.

Last, we test the fourth null hypothesis and determine whether income inequality mediates the relationship between remittances and energy poverty. The total effect shows that every 10% increase in remittances decreases energy poverty by 0.069 and both the direct and indirect effects are statistically significant. The PCGI explains most total effects as mediating factors (indirect effects). Therefore, we suggest that income inequality significantly mediates the relationship between remittances and energy poverty. This finding substantially contributes to the literature by connecting two disparate research areas, remittances, and energy. As per Apergis et al. (2022), remittances improve human capital accumulation through an increase in school attendance, improved health, and access to food and as a result, households earn a high income, which reduces income disparity. Thus, most can afford energy costs and energy poverty will be reduced.

4.5.3 Robustness Check

We use Structural Equation Modelling (SEM) with the instrumental variable, *average province rainfall times the log of distance to the nearest bank* to check the robustness of the results. We employed the year dummy as an additional control variable to control the time effect. The results show that a 10% increase in remittances decreases the MEPI by 0.013 units, suggesting that remittances reduce energy poverty. In addition, a 10% increase in remittances decreases the PCGI by 0.005 units, while a one-unit increase in the PCGI increases the MEPI by 3.19 units (see Table 4A.03 in Appendix).

Furthermore, we use the per capita Palma ratio as a proxy to measure income inequality to test the robustness of the IV mediation analysis. The results confirm that the per capita Palma ratio significantly mediates the relationship between migrant remittances and energy poverty. The results are consistent with the 2SLS and IV mediation analysis (see Table A.04 in the Appendix).

4.6 Conclusion and Policy Implications

Energy poverty measures at the household level are largely lacking or inadequate, particularly in LMICs like Sri Lanka (Jayasinghe et al., 2021; Zhang et al., 2019). Because migrant remittances are one of the most important sources of foreign exchange earnings in Sri Lanka, we used 10-year period HIES data to examine the link between migrant remittances, energy poverty, and income inequality. Because remittance is endogenous, we use an instrumental variable approach by taking the *average province rainfall times the log of distance to the nearest bank* as the instrument. The 2SLS estimations show that a 10% increase in migrant remittances reduces energy poverty by 0.042 units. The IV mediation analysis shows that remittances reduce income inequality, while income inequality increases energy poverty. Furthermore, income inequality significantly mediates the relationship between migrant remittances and energy poverty.

All Sri Lankan governments that have come to power have implemented numerous policies to reduce income inequality and poverty. For example, in 1994, the *Samurdhi Program* was launched to alleviate poverty by targeting low-income households. However, no government has made sufficient efforts to develop policies to eradicate energy poverty, so the current study's findings have significant implications for developing policies and programs to reduce energy poverty. First, the policymakers can include migrant remittances as a source of reducing energy poverty. For that, they can encourage migrant remittances by lowering the remittance transaction cost. Second, monetary authorities can find ways to reduce the cost of energy access such as introducing progressive tax rates. For example, although Sri Lanka has a 100% electricity supply, the cost of electricity excludes the poor from using electricity for lighting and cooking and also prevents the use of domestic electrical equipment. Third, although Sri Lanka achieves SDG 4 (quality education), they have little awareness of the health impacts of using biomass for cooking (Wickramasinghe, 2011). Thus, the educational authorities can develop programs to enhance awareness of the negative impacts of using dirty fuels on human health and environmental sustainability, particularly for women who undertake most household chores. Finally, this study identified that income inequality increases energy poverty. Therefore, there is an apparent link between energy poverty (SDG 7) and income inequality (SDG 10). This finding offers new policy insights for integrating various sector-specific programs and developing consistent cross-sectoral policies to achieve SDGs by 2030.

Despite the use of an extensive, nationally representative data set in this paper, some contemporary issues influencing energy poverty, such as the impact of COVID-19, are not included in our current research due to data unavailability. COVID-19 has significantly affected migrant remittances, income inequality, and energy poverty in most LMICs, including Sri Lanka. As a result, researchers will be able to address these concerns in the future.

4.7 Appendix

Table 4A.1: First-Stage OLS Regression Results

Variables	Model (1)	Model (2)	Model (3)
Average provincial rainfall times the log of distance to the nearest bank	0.0001*** (0.000)	-0.0001*** (0.000)	-0.0003*** (0.000)
Heads' Characteristics			
Gender	1.385*** (0.195)		-6.127*** (0.065)
Age (log)	0.656*** (0.051)		14.605*** (0.181)
Marital Status	-0.364*** (0.015)		-2.086*** (0.016)
Education	0.097*** (0.008)		
Primary Education			-4.826*** (0.029)
Secondary Education			-0.999*** (0.127)
Tertiary Education			-1.230*** (0.455)
Employment Sector - Government	-0.156** (0.068)		5.686*** (0.068)
Employment Sector - Private	0.457*** (0.104)		7.654*** (0.108)
Spouses' Characteristics			
Age (log)		-0.084*** (0.030)	-0.533*** (0.029)
Education		0.318*** (0.010)	
Primary Education			5.994*** (0.131)
Secondary Education			-6.166*** (0.143)
Tertiary Education			-15.814*** (0.329)
Economic Characteristics			
Other Household Income (log)	0.037*** (0.004)		-1.244*** (0.016)
Wealth Index	-0.391*** (0.023)		-1.114*** (0.026)

Household Characteristics			
Household Size		0.507*** (0.032)	-1.058*** (0.039)
Number of Children		0.536*** (0.004)	0.927*** (0.022)
Number of Females		-0.578*** (0.082)	3.013*** (0.095)
Other Characteristics			
Residential Sector - Urban			14.422*** (0.141)
Residential Sector - Rural			13.936*** (0.119)
First Stage F Statistic	30.84	118.19	432.58
No. of Observations	84483	84483	84483

Notes: Robust standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively. We use heads, spouse and other characteristics as the control variables. Model 1 includes only the characteristics of the heads, Model 2 includes spouses and other characteristics, and Model 3 considers all characteristics.

Table 4A.2: Test of the Exclusion Restriction

	Instruments		
Migrant remittances (log)	Lighting Source	Car Ownership	Car Ownership & Lighting Source
First-stage F statistics	17.38	11.08	13.12
Over identifying restrictions Hansen *J*-test and *p*-value	-	-	1.035 (0.309)

Notes: Robust standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively. The instrumented variable, remittance, is measured in log remittance. All specifications include a vector of controls that include other household income, wealth index, heads' characteristics (age, gender, marital status, education, and employment sector), spouses' characteristics (age and education), household size, number of children, number of females, and residential sectors.

Table 4A.3: SEM Results

Variables	**Coefficients/Standard Errors**
MEPI	
Remittances (log)	-0.132***(0.004)
PCGI	3.193***(0.073)
Head Education	-0.005*** (0.000)
Spouse Education	0.001**(0.000)
Household Size	0.160***(0.004)
Children Number	0.019***(0.003)
Female Number	0.055***(0.003)
Urban Sector	-0.074***(0.008)
Rural Sector	0.027***(0.007)
PCGI	

Remittances (log)	-0.047***(0.002)
Head Primary Education	0.010***(0.003)
Head Secondary Education	0.008***(0.003)
Head Tertiary Education	0.019*** (0.004)
Head Employment– Government	0.000 (0.001)
Head Employment – Private Sector	-0.003***(0.001)
Spouse Primary Education	-0.086***(0.003)
Spouse Secondary Education	-0.096***(0.003)
Spouse Tertiary Education	-0.089***(0.004)
Household Size	-0.053***(0.000)
Children Number	-0.011***(0.001)
Female Number	0.020***(0.000)
Urban Sector	0.035***(0.003)
Rural Sector	0.010***(0.002)
Year 2012	-0.022*** (0.001)
Year 2016	-0.020*** (0.001)
Year 2019	-0.012***(0.001)
Remittances (log)	
Distance to Bank (log)*Rainfall	-0.0001***(0.000)
Other Household Income (log)	0.011***(0.001)
Household Wealth Index	0.137***(0.005)
Head Gender	-0.076***(0.007)
Head Age (log)	-0.212***(0.012)
Head Primary Education	0.320*** (0.039)
Head Secondary Education	0.271*** (0.036)
Head Tertiary Education	0.396*** (0.053)
Spouse Age (log)	0.062***(0.005)
Spouse Primary Education	-1.149*** (0.033)
Spouse Secondary Education	-1.281*** (0.032)
Spouse Tertiary Education	-1.113***(0.054)
Household Size	-0.058***(0.009)
Children Number	-0.073*** (0.021)
Female Number	0.416***(0.013)
Urban Sector	0.336***(0.049)
Rural Sector	0.044 (0.044)
Year 2012	-0.082*** (0.018)
Year 2016	0.045** (0.019)
Year 2019	0.271***(0.021)
Cov (e.MEPI*e.PCAGI)	0.040***(0.003)
Cov (e.MEPI*e.Remittances)	1.188***(0.034)
Cov (e.Remittances* e.PCAGI)	0.426***(0.020)
Wald Chi2 (MEPI)	4620.56***
Wald Chi2 (PCGI)	33083.46***
Wald Chi2 (Remittances)	4899.81***

Notes: standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively.

Table 4A.4: IV Mediation Analysis

Pathways	Direct Effect	Indirect Effect	Total Effect
Remittances to MEPI	-0.686*** (0.009)		
Remittances to Per Capta Palma Ratio	-14.33*** (0.178)		
Per Capta Palma Ratio to MEPI (Controlling for the treatment)	0.048** (0.000)		
Remittances to Per Capita Palma Ratio to MEPI	-0.005*** (0.001)	-0.681*** (0.001)	-0.686*** (0.001)

Notes: standard errors in parentheses; ***,**, and * represent significant at the 1%, 5% and 10% levels, respectively.

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Chapter 5: Covid - 19, Energy Crisis and Sri Lankan Economy: A Matter of Migrant Remittances?

5.1 Introduction

The beginning of 2022 has been marked by a global energy crisis for most economies, owing to substantial interruptions in energy markets caused by two unanticipated events: the coronavirus pandemic and Russia's invasion of Ukraine (Berahab, 2022; United Nations, 2022). Sri Lanka is one of the nations that has received the most international attention in recent years due to its severe energy crisis. Sri Lanka's government has officially declared that the country is experiencing its worst energy crisis in 73 years (Khalid, 2022). The country experienced the longest power outage in the world, lasting 13 hours per day (The Guardian, 2022a). People wait in miles-long queues in front of fuel stations to load up their vehicles with petrol and diesel. Soldiers have been assigned to fuel stations to keep customers calm as their frustration increases from days of waiting in lengthy queues. Many human deaths were reported as people waiting in fuel queues for extended periods without food and sleep (Gupta, 2022). In addition, the government forces people to cook with fuelwood or other unclean fuel alternatives due to a lack of Liquefied Petroleum Gas (LPG) in the market (The Guardian, 2022b).

Furthermore, fuel shortage has extremely detrimental effects on Sri Lankan key industries like agriculture, fishing, health care, textiles, tourism and education, with the majority operating at suboptimal levels. For example, according to The Guardian (2022b), retail stores have been forced to close due to a lack of power to run refrigerators and air conditioners. Doctors have declared a medical crisis as pharmacies and hospitals run out of essential drugs. As food supplies diminish, warnings have been issued that starvation may be imminent for the 22 million Sri Lankans. Many Fridays have been declared a holiday for public offices due to transport issues, and they have been asked to run without air conditioners and conserve energy. Furthermore, schools and tertiary education institutions have been halted for several months. Several protests were held throughout the country, with the Colombo serving as the focal point to force the government to resign. As a result of these protests, the president and the prime minister had to resign, causing political instability in the country.

All these actions will undoubtedly harm the Sri Lankan economy in the short, medium, and long term. Therefore, policymakers are obligated to carry out an in-depth analysis of the energy crisis and formulate effective solutions immediately. Accordingly, the primary objective of this paper is to examine the root causes of the Sri Lankan energy crisis and to discuss how the crisis affects Sri Lankan energy poverty and the achievement of Sustainable Development Goal (SDG) 7 by 2030. In addition, this paper analyses the crisis in the economic context and provides policy recommendations to manage the energy crisis.

5.2 Reasons for Sri Lankan Energy Crisis

Sri Lanka's energy crisis is prompted by a persistent depletion of foreign reserves, commonly known as a foreign exchange or forex crisis. Sri Lanka requires massive foreign reserves to finance fuel imports because fuel is the country's most expensive and major import item. In 2021, fuel imports accounted for 18.1% of total imports, totalling USD 3742.9 million (CBSL, 2021). However, Sri Lanka's official foreign reserves have plummeted recently (see Figure 5.1). This has tremendously affected the energy sector, which relies entirely on fuel imports.

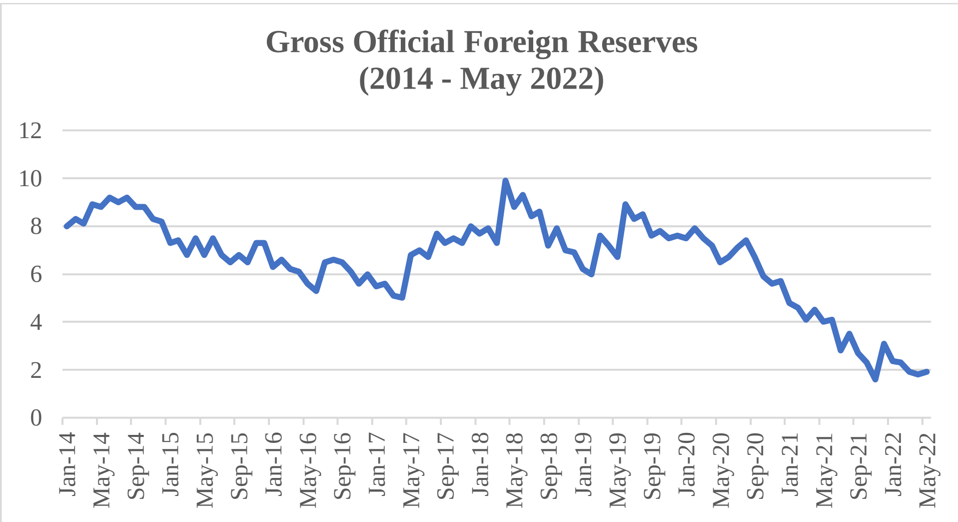

Figure 5.1: Sri Lanka's Gross Foreign Reserves

Source: CBSL (2022c)

Figure 1 clearly illustrates that beginning in 2019, Sri Lanka's foreign reserves have been steadily depleted, finally dropping to a record low of less than USD 2 billion by May 2022. A variety of factors contributed to initiating this forex crisis. First, there was a substantial decline in tourist arrivals due to a series of terrorist bombings in churches and luxury hotels in Colombo in April 2019. As a result, from March to June 2019, tourist revenue fell by around 85%, from USD 460.5 to 71.2 million. This was worsened further by the Covid-19 pandemic, which reduced tourist earnings by a massive portion, from USD 1,914 million in 2019 to USD 508 million in 2020 and USD 194 million in 2021. As a percentage, the drop in tourism revenue in

2021 compared to 2019 is approximately 52% (CBSL, 2022c). Tourist arrivals in 2022 fell further due to Russia's invasion of Ukraine in February 2022 because Russia is one of the major countries sending tourists to Sri Lanka. Second, the Covid-19 pandemic forced thousands of migrants to return home, causing a substantial decline in remittance income from USD 7.14 billion in 2020 to USD 5.49 billion in 2021 to USD 3.31 billion in 2022 (CBSL, 2021, 2022d). In 2022, remittances are reported to be 39.65% lower than in 2021(CBSL, 2022g).

Third, prior to the Covid pandemic, the newly elected government introduced an expansionary fiscal policy by reducing taxes. For instance, the Value Added Tax (VAT) rate was reduced from 15% to 8%, the corporate tax rate was reduced from 28% to 24%, and the nation-building tax, the pay-as-you-earn tax, and economic service charges were eliminated. This policy resulted in a loss of approximately 2% of the Gross Domestic Product (GDP) and 1 million taxpayers (IRD, 2021). The government's revenue has dropped significantly, resulting in a massive budget deficit beginning in 2019. In 2019, 2020, and 2021, the budget deficit accounted for 9.65%, 11.1%, and 12.24% of GDP, respectively (CBSL, 2022f). This contributed to expanding the Current Account (CA) and Balance of Payments (BOP) deficit, requiring further foreign debts. Finally, in April 2021, the government decided to move entirely to organic farming due to the increased use of agrochemicals that have adverse health and environmental implications. The government has prohibited all agrochemical imports. Even though this action improves sustainable food systems, the sudden policy shift reduced agricultural production because over two million farmers left farming. As a result, total food production dropped by 40%, and Sri Lanka had to import rice, the nation's staple meal, for the first time in decades. The production of tea, the country's prime export, fell by 18%, reducing its foreign exchange revenues significantly (Guzman, 2022).

In summary, a drop in tourism income, a decline in migrant remittances, a 2019 tax cut, and a policy decision to shift to organic farming caused the Sri Lankan forex crisis, which in turn led to the energy crisis due to a lack of foreign reserves to import fuel. In addition to these factors, the Central Bank's sudden decision to switch to a floating exchange rate system in March 2022 and Russia's invasion of Ukraine in February 2022 magnifies the energy crisis by inducing an unanticipated surge in fuel prices. With the introduction of the floating exchange rate system, the Sri Lankan rupee depreciated up to 60% of its value against the US dollar in a single month. For example, by June 2022, the Sri Lankan rupee trades at, on average, 360 per USD, compared to 203 per USD in March, when the float was announced (CBSL, 2022e). Due to these factors, the prices of 95-octane petrol, 92-octane petrol, and auto diesel skyrocketed approximately by

95%, 85%, and 161%, respectively, in June compared to March 2022 (CEYPETCO, 2022). These circumstances place Sri Lanka in a vulnerable position because the country requires massive foreign reserves to import essential items such as food, medicine, and fuel and repay foreign debt totalling nearly USD 51 billion (Guzman, 2022).

5.3 Energy Crisis, Energy Poverty, and SDG 7

The Sri Lankan government is obligated to provide immediate solutions to the prevailing energy crisis in the country. Because energy is a fundamental requirement for all living beings and is essential for sustainable development (Guta, 2018; Mendoza et al., 2019). Furthermore, a persistent energy crisis leads to energy poverty, which prevents billions of people from accessing affordable, modern, and eco-friendly energy services (Reddy et al., 2000). It has severe implications for human health, education, well-being and environmental sustainability (Awaworyi Churchill et al., 2020; Zhang et al., 2019). More importantly, energy poverty hinders the achievement of SDG 7, which ensures access to affordable, reliable, and modern energy for all by 2030.

According to IEA (2020), Sri Lanka is one of the South Asian countries with 100% access to electricity, whereas around 4.2% of the population in South Asia does not (see Figure 5.2). However, 68% of Sri Lankans do not have access to clean cooking fuels and technologies, compared to 40% of South Asians (see Figure 5.3).

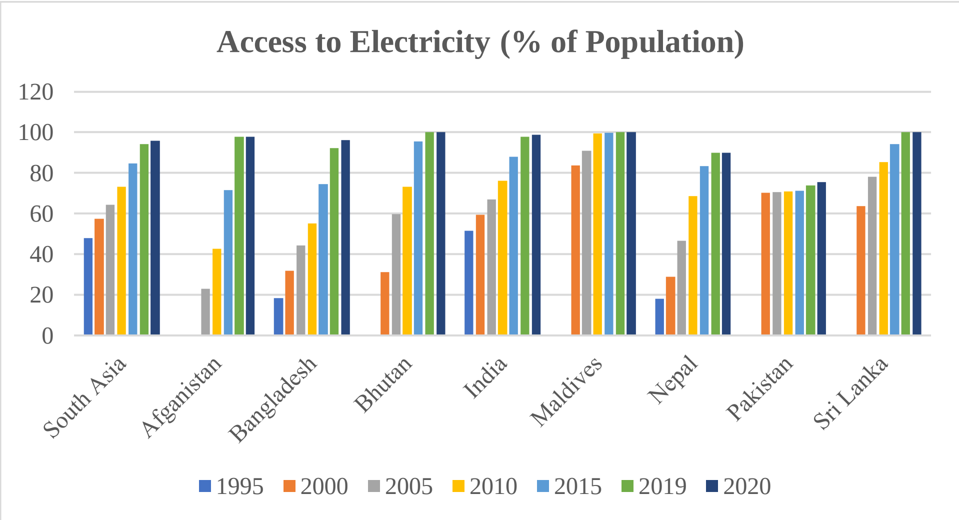

Figure 5.2: Access to Electricity in South Asia

Source: World Bank (2022b)

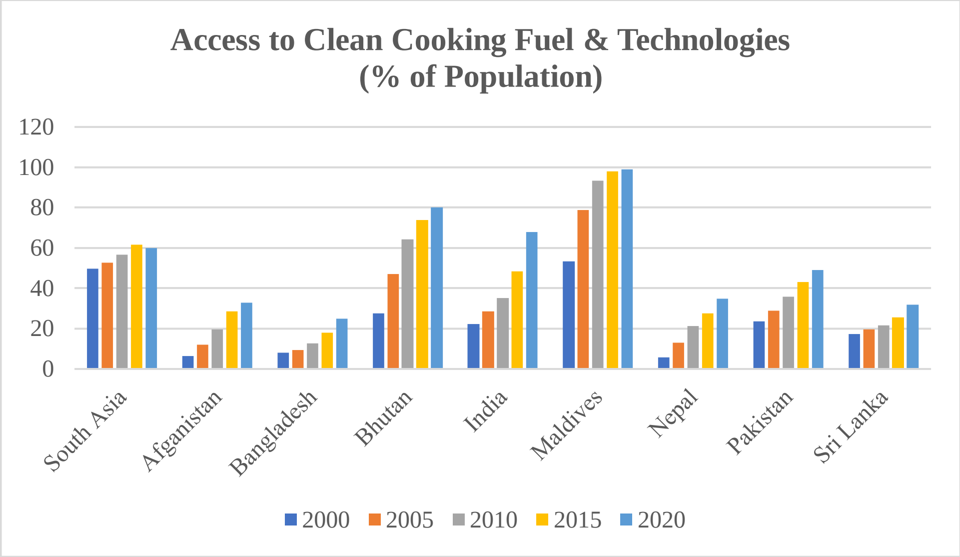

Figure 5.3: Access to Clean Cooking Fuels and Technologies in South Asia

Source: World Bank (2022a)

Both figures show that access to electricity and clean cooking fuels in South Asian countries has been gradually increasing, but efforts need to accelerate to meet SDG 7 by 2030. Figure 2 shows that Sri Lanka has 100% access to electricity, but the current energy crisis causes them to be dark for nearly half of the day. According to statistics, power outages in Sri Lanka lasted approximately 13 hours daily. This was the most extended power outage recorded worldwide (The Guardian, 2022a). Even though the country has 100% access to electricity, this will negatively impact the achievement of SDG 7 by 2030.

As per figure 3, Sri Lanka is the second lowest South Asian country with access to clean fuel and cooking technologies. This will worsen further as the country ran out of LPG for several months due to a lack of foreign reserves to import LPG. The government also forced people to cook with firewood and other dirty fuel alternatives, despite clean fuels such as electricity and LPG. As a result, energy poverty will further rise because the utilization of dirty fuels for cooking accounts for the most significant proportion of energy poverty in Sri Lanka (Jayasinghe et al., 2021; Wijayarathne et al., 2022b). Figure 5.4 shows the access to clean cooking and technologies in Sri Lanka as a percentage of the population from 2000 to 2020.

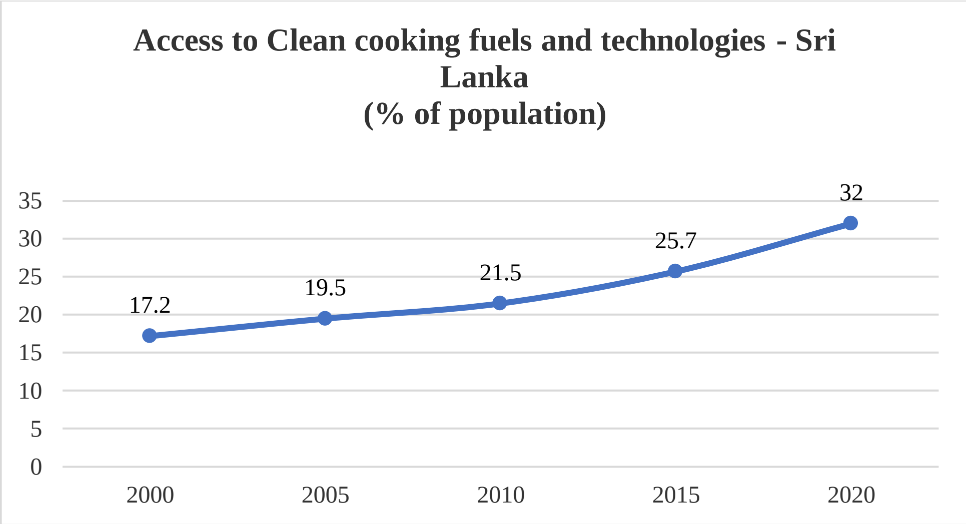

Figure 5.4: Access to Clean Cooking Fuels and Technologies in Sri Lanka

Source: World Bank (2022a)

According to the above figure, although clean fuel usage is gradually increasing, about 68% of Sri Lankans still use solid fuels like firewood, biomass, and crop residue for cooking (World Bank, 2022a). The incomplete combustion of these fuels emits extremely harmful greenhouse gases and directly contributes to indoor air pollution (Balakrishnan et al., 2018; Muller & Yan, 2018). As a result, using dirty fuel for cooking has detrimental effects on human health and environmental sustainability. In addition, this will hinder the achievement of SDG 7. Therefore, appropriate and immediate policy efforts are required to minimize the use of polluting fuels for cooking to reduce energy poverty and achieve SDG 7.

5.4 Energy Crisis and Migrant Remittances

Policymakers and other responsible authorities have proposed short and long-term strategies to address Sri Lanka's current energy crisis. Most of them have advocated encouraging migrant remittances, the financial or in-kind transfers made by migrants directly to their origin countries (IOM, 2019), as a quick measure to overcome the existing energy crisis. Because remittance flows are a stable source of capital compared to the other kinds of private capital flows (such as exports, FDI, and official aid) because they do not depend on external factors like cyclical fluctuations and external shocks (Koechlin & Leon, 2007). They are the critical pillars of foreign exchange reserves in most developing countries.

Sri Lanka is one of the South Asian nations that received substantial amounts of migrant remittances. Sri Lanka received the most remittances from South Asia as a percentage of GDP up until 2000. From 2000 to date, Sri Lanka has been the region's second most outstanding recipient of remittances as a percentage of GDP (see Figure 5.5).

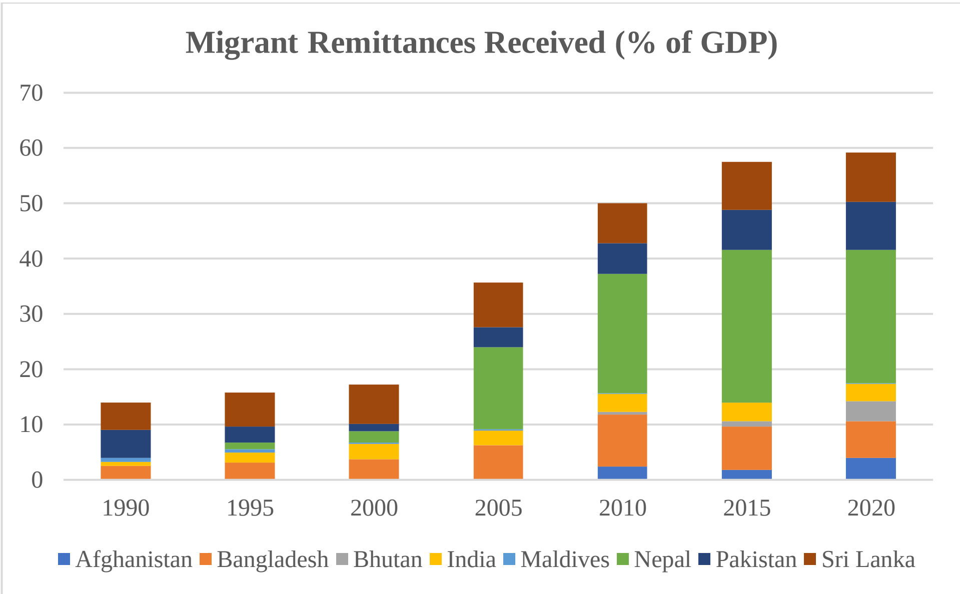

Figure 5.5: Migrant Remittances Received for South Asia as a percentage of GDP

Source: World Bank (2022c)

Workers' remittances have been integral to Sri Lanka's foreign currency inflows, providing a significant buffer against the country's expanding trade deficit. In Sri Lanka, workers' remittances have covered almost 80% of the annual trade deficit over the last two decades as a significant source of foreign exchange earnings (CBSL, 2022h). In 2020, migrant remittances totalled USD 7140 million and 8.8% of the GDP (CBSL, 2021). However, after Covid-19, the number dropped to USD 5490 million in 2021, reporting the lowest foreign remittances in recent years, and it accounted only for 6.4% of the GDP (CBSL, 2022c). The total remittances received from 1990 to 2022 for Sri Lanka in millions of dollars (see Figure 5.6) and as a percentage of GDP (see Figure 5.7) is shown below.

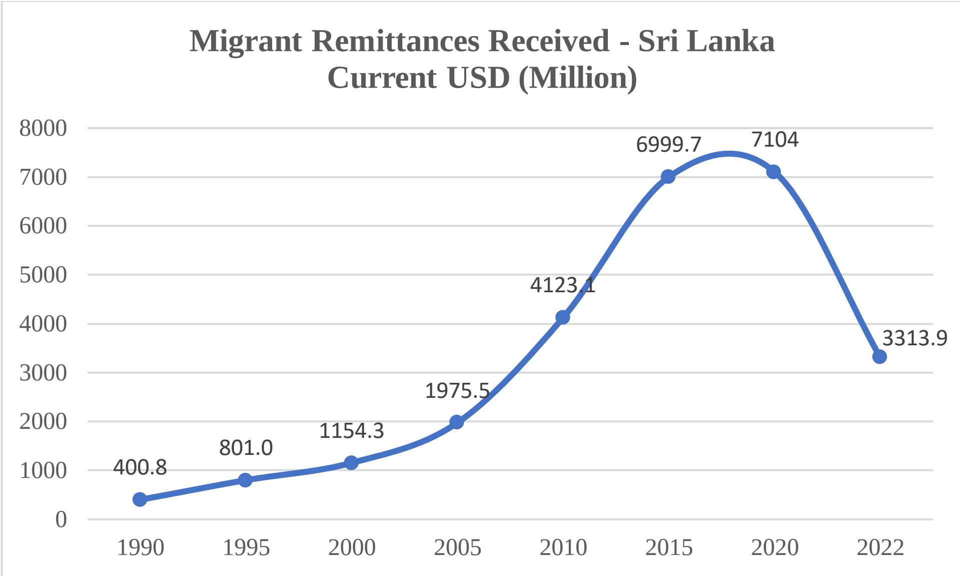

Figure 5.6: Migrant Remittances Received to Sri Lanka (in USD Million)

Source: CBSL (2022c)

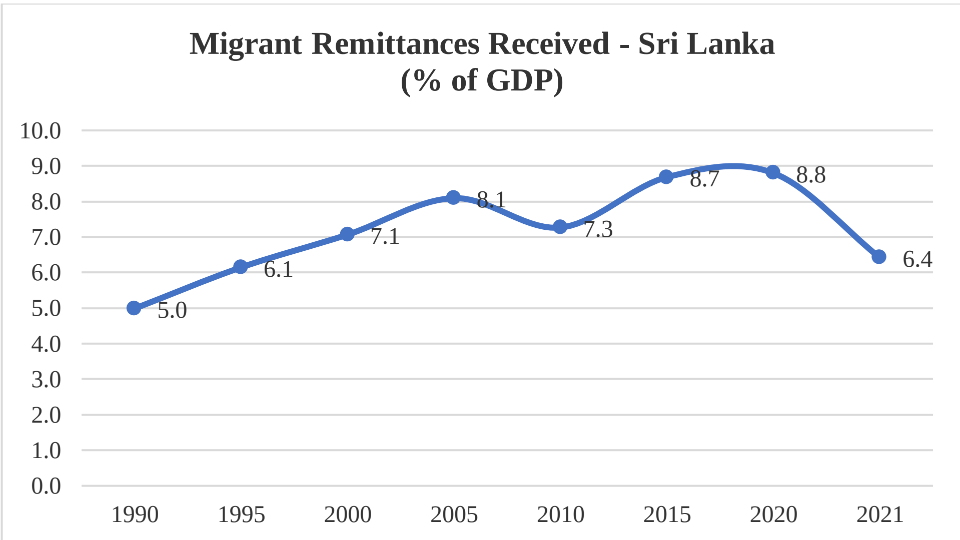

Figure 5.7: Migrant Remittances Received to Sri Lanka (% of GDP)

Source : World Bank (2022c)

In 2021, Sri Lankans living abroad remitted USD 5491 million to the country. However, they only sent back USD 3314 million in 2022, which is a 39.65% reduction compared to the previous year (CBSL, 2022g). The decline in migrant remittances mainly led to the depletion of Sri Lanka's foreign reserves, precipitating a forex crisis at the end of 2021. This demonstrates that an increase in remittances can significantly contribute to a rise in foreign reserves, thus alleviating the current energy crisis in Sri Lanka by enhancing the capability of importing fuels.

A study conducted by Wijayarathne et al. (2022a) in Sri Lanka found that a 10% increase in migrant remittances reduces energy poverty by 0.0034 units. Furthermore, Wijayarathne et al. (2022b) found that a 10% rise in migrant remittances increases clean fuel use by 0.034 units in the same context. Therefore, we can predict a 39.65% drop in migrant remittances in 2022 compared to 2021; the energy poverty would increase by 0.013 units in 2022. We predict that the drop in clean fuel use for cooking, which amounts to 0.13 units, will be the largest contributor to this energy poverty. With our predicted values of energy poverty in Sri Lanka, the energy poverty and use of clean cooking fuel are moving backwards even further, indicating that Sri Lanka cannot achieve SDG 7 as expected. The United Nations also stated in 2020 that Sri Lanka would be unable to meet SDG 7 by 2030 (United Nations, 2020) before this energy crisis. Accordingly, we predict that Sri Lanka will not meet SDG 7 by 2030 in its status quo; therefore, appropriate strategies to address the energy crisis should be implemented immediately.

5.5 Energy Crisis: An Economic Analysis & Discussion

5.5.1 Twin Deficit Hypothesis

Sri Lanka has been suffering from colossal budget and CA deficits for many years. As a result, Sri Lanka is a classic example of the twin deficit hypothesis, which states continuous budget deficit puts more pressure on the CA deficit (Epaphra, 2017). Figure 5.8 clearly shows the existence of a twin deficit in Sri Lanka.

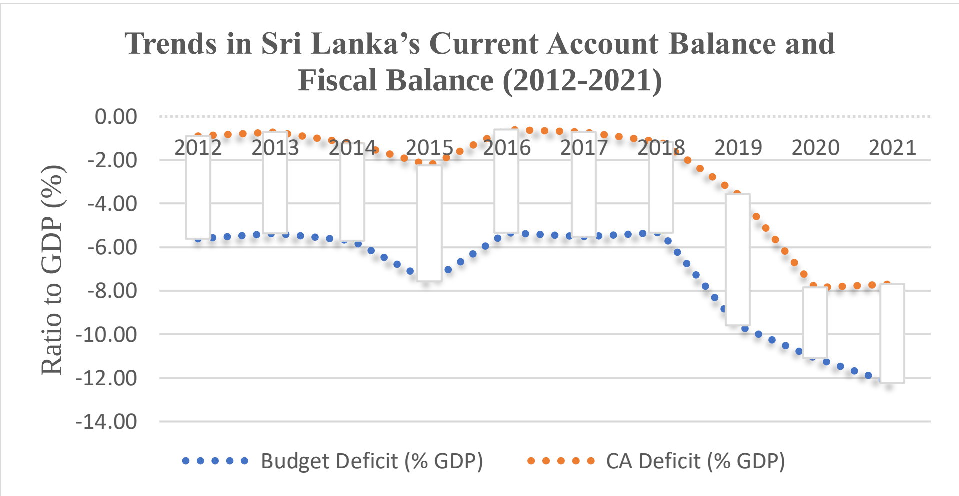

Figure 5.8: Sri Lankan CA and Fiscal Balance

Source: CBSL (2022f)

5.5.1.1 Budget Deficit

The main cause of the budget deficit is the introduction of the expansionary fiscal policy in 2019 by reducing taxes, which caused to loss of about 1 million taxpayers and 2% GDP (IRD, 2021). The situation has worsened further because of the Sri Lankan government's irrational decision to fully transition to organic agriculture due to declining crop harvest. These measures, as well as the Covid-19 pandemic issues such as island-wide lockdowns, expenditure for Covid-19 vaccination and other Covid-related medicines, significantly expanded Sri Lanka's budget deficits from 2019. In line with Keynesian theory, the increase in the budget deficit surged the CA deficit due to an unexpected rise in import demand (Bhowmick, 2022).

5.5.1.2 CA Deficit

In addition to the effect of the budget deficit, the CA deficit widened in recent years due to a drop in migrant remittances and tourist revenue. Loss of tourism income reduced service exports, and loss of migrant remittances reduced the secondary income of the current account. The relationship between CA balance, tourism income, and remittances is shown in Figure 5.9.

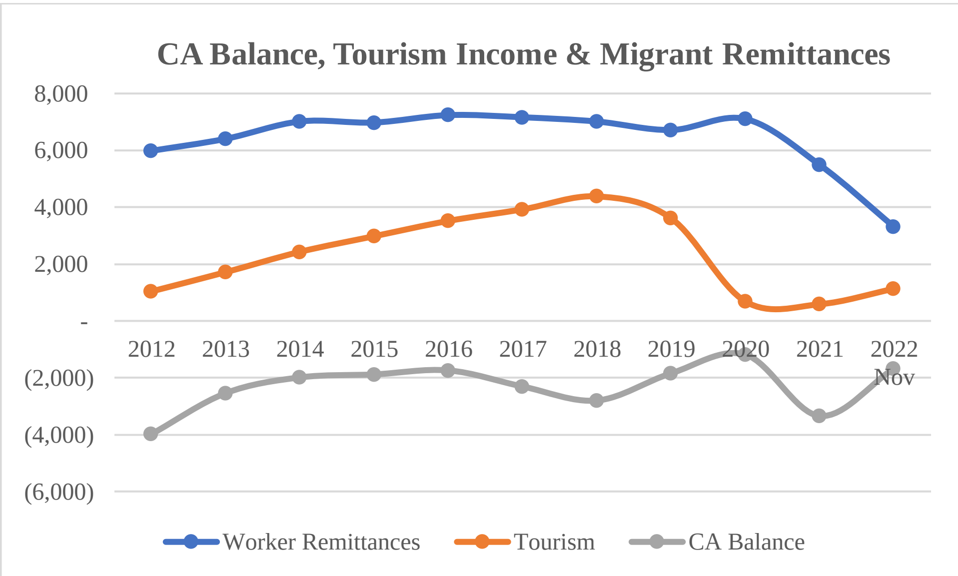

Figure 5.9: CA Balance, Tourism Income, & Migrant Remittances

Source: CBSL (2022c)

Figure 5.9 shows a similar trend in CA balance and migrant remittances received starting from 2019. Since tourism revenue remains consistent in 2020 and 2021, there is a strong correlation between the CA balance and remittances received. Accordingly, it is evident that the primary cause of Sri Lanka's CA deficit is the drop in migrant remittances because of Covid-19. The growing CA deficit exacerbated the BOP deficit and caused it to deplete Sri Lanka's foreign reserves rapidly. As a result, the government could not meet the people's demand for even basic needs such as food, medicine, and fuel. This caused many crises in Sri Lanka, including a food crisis, a medical crisis, and an energy crisis.

5.5.2 Exchange Rate Vs Inflation Rate

There is a significant positive association between the exchange rate and the inflation rate (Deka et al., 2022; Fisher, 1930; Yang et al., 2022). An increase in the exchange rate (depreciation of the domestic currency) increases net exports (Yang et al., 2022). The depreciation of the domestic currency raises import costs (thus discouraging imports) and reduces the cost of exports (thus encouraging exports). Positive net exports generate a trade surplus in the BOP account, increasing foreign reserves (Salvatore, 2013). However, if imports are essential for a country, even at higher prices, they have to import goods and services, which will cause rising inflation.

In Sri Lanka, fuel is the primary and essential import item. Therefore, the depreciation of the Sri Lankan rupee against the US dollar raises the cost of fuel imports. This causes fuel prices to rise in the domestic market. Furthermore, because fuel is the primary intermediary product for the vast majority of the country's goods and services, the prices rise sharply, causing hyperinflation. Figure 5.10 depicts the positive relationship between the exchange rate and the inflation rate in Sri Lanka over the last decade.

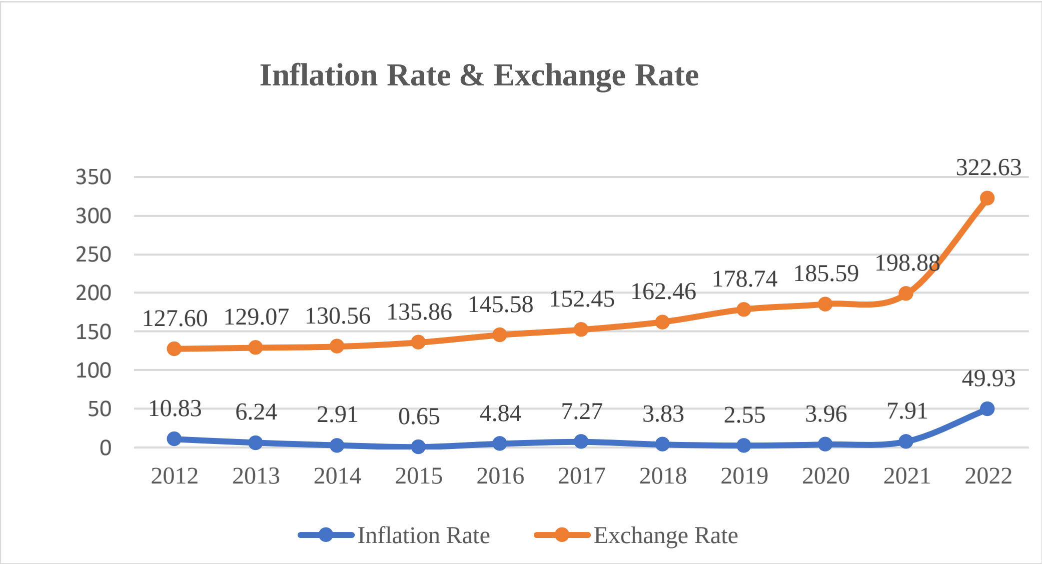

Figure 5.10: Relationship between Exchange Rate and Inflation Rate in Sri Lanka

Source: CBSL (2022a); CBSL (2022b)

The Central Bank's decision to float the exchange rate in March 2022 negatively affected the inflation rate. On average, the Sri Lankan rupee depreciated by around 42.68% against the US dollar from March 2022 to January 2023 (CBSL, 2022b). As the country is entirely dependent on fuel imports, fuel prices have risen to about 90% (CEYPETCO, 2022). As a result, the inflation rate in Sri Lanka has skyrocketed since April 2022 (see Figure 11). For example, the overall inflation rate in January 2023 is 53.2%, representing a 147.4% increase compared to March 2022 (CBSL, 2022b).

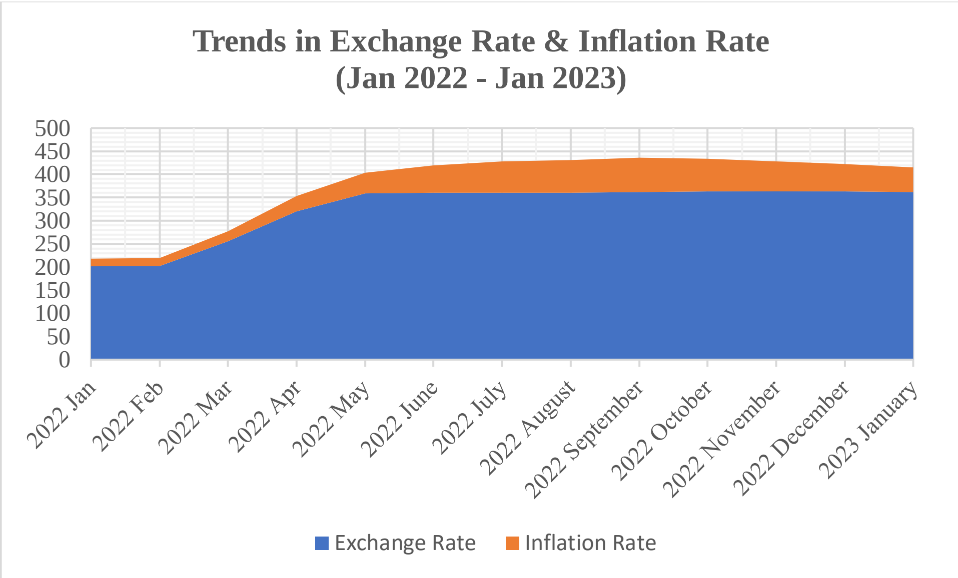

Figure 5.11: Trends in Exchange Rate and Inflation Rate in Sri Lanka

Source: CBSL (2022a); CBSL (2022b)

Figure 5.11 clearly illustrates how an increase in the exchange rate increases the inflation rate from January 2022 to January 2023 in Sri Lanka. A higher inflation rate has numerous adverse effects on Sri Lankans because it decreases their real income, diminishing their ability to meet basic needs like food, medicine, and fuel. The result of this is a decline in the people's standard of living. For instance, the daily rise in food prices significantly impacts people's diets, and according to UNICEF (2022), Sri Lanka has ranked sixth in the world for child malnutrition in 2022.

5.6 Conclusion and Policy Implications

The Sri Lankan government has introduced and implemented numerous strategies to address the country's most prominent forex crisis. The country owes more than USD 50 billion to foreign lenders in 2022 (CBSL, 2022g). The Sri Lankan government has already negotiated with the International Monetary Fund (IMF) to obtain a USD 3 billion loan. Since the beginning of the year, India has provided Sri Lanka with around USD 3 billion in emergency assistance in the form of debt deferral, swap lines, a credit line, and a term loan of USD 1 billion. The World Bank has agreed to lend USD 600 million to Sri Lanka. The G7 group of countries, which includes Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States, has stated that they all support Sri Lanka in reducing debt obligations and rescheduling payback periods. The country has requested low-cost oil supplies from Russia and Qatar to cut the cost of petrol (Perera, 2022).

Sri Lanka raised the VAT from 8% to 12%, the corporate tax from 24% to 30%, the highest personal income tax rate from 18% to 34%, and withholding tax on employment income was made mandatory (IRD, 2022). This contractionary fiscal policy has a more significant positive impact on reducing the budget deficit. Furthermore, the current government has restarted imports of agrochemicals and reversed the decision to transition to fully organic farming. The cabinet has approved for state fertilizer firms to import for the 2022/2023 Maha season. Discussions with the World Bank, Asia Development Bank, and other international financial institutions have begun to obtain funds to import the necessary fertilizers (Economynext, 2022). More importantly, with the new budget of 2023, Sri Lankan government expect to increase overall expenditures by 20% to $9.1 billion, from $7.8 billion in the previous budget. These expenditures will concentrate more on farmers, fishermen, and low-income earners, who have been among the hardest hit by the current economic crisis. The interim budget also aims to lower the budget deficit to 6.8% in 2023 (ANS, 2022). According to the twin deficit hypothesis, reducing the budget deficit reduces the CA deficit. This will positively influence the BOP balance and foreign reserves of the country.

To enhance tourism income, the Sri Lankan government launched many programs such as global tourism promotional campaigns, providing visa exceptions for selected countries, and developing physical and digital infrastructure facilities such as cable car and train services (SLTDA, 2022). Furthermore, SLTDA (2022) have explored new drivers of tourism, including wellness tourism (such as meditation, yoga, retreat, and Ayurveda medicine programs to improve the physical and well-being of tourists), educational tourism (short-term and long-term educational programs like exchange and homestay program for international students), and philanthropical tourism (such as charity work, and agricultural work). In addition, the Central Bank's monetary board regulates tourist hotel providers to accept payments from non-residents only in foreign currency (CBSL, 2021). These actions are likely to boost tourism earnings in the coming years. Since tourism is still a significant source of net currency earnings for a country, it will increase service export income and thus have a positive impact on the country's foreign reserves. It also contributes to economic growth, job creation, and the reduction of regional income disparities.

Furthermore, the government has implemented numerous incentive programmes to encourage migrants to transfer remittances via formal channels. This primarily intends to prevent unlawful transfers such as "Undiyal" and "Hawala" methods and replenish depleted foreign exchange reserves. According to CBSL (2022i), the Central Bank implemented an "Additional Incentive Scheme on Inward Workers' Remittances" to compensate migrant workers with an additional Rs. 20 for each US dollar remitted. They also announced an incentive scheme to reimburse migrant employees' expenses of up to Rs. 1,000 for each transaction over Rs. 20,000 when sending money to Sri Lanka. Furthermore, the government aims to provide migrant workers with low-interest loans, expanded duty-free concessions, pension plans, and insurance coverage. Recently, the facilities provided to migrant workers were expanded by providing vehicle import permits to migrant workers who remit USD 100,000 per year through banks. Moreover, they grant VAT concessions on purchasing specific goods based on the amount of remittances sent by migrant workers (Shan, 2022).

Compared to other measures taken by the government, it seems they have formulated more policies focusing on migrant remittances. Migrant remittances play a significant role in the Sri Lankan economy because, on average, it contributes around 8.5% to the GDP and cover 80% of the trade deficit. More specifically, migrant remittances contribute to decreasing energy poverty and achieving SDG 7. For example, a 10 % increase in migrant remittances increases clean cooking fuel usage by 0.034 units and reduces energy poverty by 0.0034 units. However, compared to 2021, migrant remittances have declined by around 40% in 2022. Therefore, we predict that energy poverty has risen by 0.014 units and clean cooking fuel use has dropped by 0.14 units in Sri Lanka. Accordingly, Table 5.1 shows the forecast values of a change in migrant remittances that affect clean fuel use and energy poverty in Sri Lanka.

Table 5.1: Forecasts for Energy Poverty and Clean Cooking Fuel Use based on Remittances

Expected % increase in migrant remittances (per month)	Expected decline in energy poverty	Expected growth in clean cooking fuel use	Expected required months to go back to the 2021 poverty level
1%	0.00034	0.0034	April 2026
2%	0.00068	0.0068	August 2024
5%	0.0017	0.017	August 2023
10%	0.0034	0.034	April 2023
15%	0.0051	0.051	March 2023
20%	0.0068	0.068	February 2023

Source: Authors' calculations using Wijayarathne et al. (2022a); (Wijayarathne et al., 2022b)

Table 5.1 shows that if migrant remittances increase by 1% per month beginning in January 2023, it will take another 40 months to return to the poverty level of 2021. If remittances increase by 2%, 5%, 10%, 15% and 20% per month, it will take another 20, 8, 4, 2 and 1.5 months, respectively, to recover to the 2021 poverty level. As we predicted, if the migrant remittance increases, it causes to reduce energy poverty showing a positive sign to meet SDG 7 by 2030. Furthermore, remittances and the CA balance have been trending in the same direction in recent years, and an increase in migrant remittances will reduce the CA deficit. As a result, it will positively contribute to the BOP balance and help resolve the current forex crisis. Solving the forex crisis also can reduce the energy crisis by enhancing the capability to pay for fuel imports.

5.7 The Way Forward

The proper adoption of the above initiatives will undoubtedly solve Sri Lanka's current energy crisis. However, to address the long-term energy crisis, Sri Lanka should switch to renewable energy. Renewable energy is the most efficient source for Sri Lanka, which has plenty of sunlight and wind. Developing a resilient clean energy supply network can help to protect the economy from external shocks. Policies have been implemented to transition Sri Lanka to carbon neutrality and 100% renewable energy generation by 2050. They hope to generate 2000 megawatts of solar energy per year by 2023. Furthermore, the government recently cancelled plans for two coal-fired power plants due to environmental concerns. The necessary changes are being made to the 2014 renewable energy legislation in order to expedite the approval and implementation of solar and wind power projects (Aneez, 2022).

A recent study conducted by Deka et al. (2022) found that an increase in the use of renewable energy causes the exchange rate to appreciate, lowering the inflation rate. Furthermore, they discovered that both the inflation rate and the exchange rate have a positive impact on the use of renewable energy. This can happen because more use of renewable energy decreases the need for fuel imports, thus positively affecting the exchange rate. Therefore, we can recommend that the use of renewable energy cause favourably on the CA and BOP balances and increase foreign reserves by resolving the forex crisis. On the other hand, an appreciation of the exchange rate lowers inflation. This will improve people's real income, allowing the majority to meet their fundamental demands. As a result, the country's prevailing crises (such as the food and energy crises) will be resolved by improving the people's standard of living and well-being. Moreover, using renewable energy contributed to reducing energy poverty in the country, allowing the achievement of SDG 7.

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Chapter 6: Conclusion

Energy services are vital contributors to economic, social, and human development (Alem et al., 2016; Guta, 2018). However, about 733 million people worldwide live without electricity, and 2.4 billion people do not have access to clean cooking fuel and technologies (IEA, 2022), reflecting widespread energy poverty. Energy poverty has severe negative impacts on human health, education, well-being, and environmental sustainability (Awaworyi Churchill et al., 2020; Chevalier & Ouédraogo, 2009; Sovacool, 2012; Zhang et al., 2019). As a result, the United Nations has designated energy as the seventh Sustainable Development Goal (SDG 7), ensuring universal access to affordable, reliable, and modern energy by 2030. According to IEA (2022), the majority of countries will fail to meet SDG 7 as expected, which will be particularly tricky in the case of cooking fuel.

Chapter 2 examined the non-price determinants of cooking fuel choice at the household level using four waves of Sri Lankan HIES in 2009, 2012, 2016, and 2019. As the dependent variable of cooking fuel type has three nominal, unordered alternatives (solid, transitional, and clean), random-effects panel multinomial logit regression was used to identify demographic, socio-economic, household and housing characteristics. The findings showed that household income, household wealth, marital status, age and education of the head, education of the spouse, household size, and the number of children under five were statistically significant for clean cooking fuel choice. Housing characteristics such as the number of bedrooms, drinking water sources, and housing materials (type of wall, floor, and roof) were also vital in the selection of clean fuels for cooking. Geographical location (urban and rural sectors) was statistically important for obtaining clean cooking fuel compared to the estate sector. Chapter 2 also examined the synergy between SDGs 7, 6, and 4 using advanced sustainability analysis. The results showed that SDG 4 and 6 had a strong synergetic effect on SDG 7

Chapter 3, examines how migrant remittances affect the choice of different types of cooking fuels. A few studies have looked into the impact of migrant remittances on fuel consumption (Hassan, 2020; Manning & Taylor, 2014; Taylor et al., 2011; Ye & Koch, 2021). However, a clear link between migrant remittances and clean fuel consumption is challenging to establish as many factors drive the use of remittances. Despite this, previous research showed that migrant remittances substantially affect household wealth (Baiyegunhi & Hassan, 2014; Rahut et al., 2016), and household wealth significantly influences clean fuel consumption (Adams & Cuecuecha, 2010; Mahapatro, 2016). This happens because wealth is a stock variable rather than a flow variable, and therefore, it is likely to influence the use of clean fuel. This study integrated two distinct areas of the literature: remittances and energy, through household wealth. First, the study investigated whether clean fuel consumption differed between migrants and non-migrants, using the propensity score matching method. The results showed that migrant households were at least 5.7% more likely to use clean fuels for cooking than non-migrant families. As remittances are endogenous, the control function (CF) approach and instrumental variable (IV) mediation analysis were used, taking the average province rainfall times the log of distance to the nearest bank as the instrument. According to CF analysis, a 1% increase in remittances boosted clean and transitional fuel use by about 0.04 units compared to solid fuels. Furthermore, the IV mediation analysis showed that remittances increased household wealth, which in turn, increased the use of clean cooking fuels, indicating that household wealth has a significant mediating impact on the relationship between migrant remittances and the type of cooking fuel used.

The massive use of solid fuel for cooking significantly contributes to energy poverty. Chapter 4 thus investigated how migrant remittances affect energy poverty, using the pseudo-panel approach. Only a few studies have been conducted to date to investigate this association (Agradi, 2023; Barkat et al., 2023; Hosan et al., 2023), and their conclusions about the mechanism by which remittances affect energy poverty are unclear. However, most previous research shows that migrant remittances have a significant impact on income inequality (Acosta et al., 2008; Azizi, 2021; Bang et al., 2016), and income inequality has a substantial impact on energy poverty (Bardazzi et al., 2021; Galvin, 2019; Galvin & Sunikka-Blank, 2018; Nguyen & Nasir, 2021). This study therefore integrated two distinct areas of the literature – remittances and energy – through income inequality. Energy poverty was operationalized using the Multidimensional Energy Poverty Index (MEPI), and income inequality was operationalized using the Per Capita Gini Index. Because remittance is endogenous, the instrumental variable approach was used, taking the average province rainfall times the log of distance to the nearest bank as the instrument. The 2SLS results showed that remittances significantly reduced energy poverty. The Instrumental Variable (IV) mediation analysis results indicated that remittance had a negative association with income inequality, and income inequality had a positive association with energy poverty. Notably, income inequality significantly mediated the relationship between remittances and energy poverty.

After identifying the effect of migrant remittances on cooking fuel selection and energy poverty, Chapter 5 generalized the findings to the current energy crisis experienced by Sri

Lanka, with a discussion of the causes of the crisis and its economic implications. Because of the energy crisis, migrant remittances declined by around 40% in 2022 compared to 2021 (CBSL, 2022). According to the findings of Chapters 3 and 4, a 1% increase in remittances decreased clean fuel consumption by 0.037 units and decreased energy poverty by 0.004, respectively. As a result of a 40% decline in remittances, clean fuel use declined by 0.16 units and energy poverty rose by 0.0016 units in Sri Lanka during the year 2022.

6.1 Policy Implications

The findings of this thesis has several policy implications for achieving SDG 7 by 2030. In the first stage, solid cooking fuel should be recognised as a major contributor to energy poverty, and its reduction should be incorporated into the national energy policy. The relevant authorities can first use the findings of Chapter 2 to gain a thorough understanding of the crucial demographic, socioeconomic, and housing factors that promote the use of clean fuel for cooking. Chapter 2's findings on the synergy between SDGs 7, 6, and 4 can also be used to develop new policy insights for national energy policy through the integration of sector-specific programmes and the development of consistent cross-sectoral policies. For example, policymakers could design and implement an educational programme aimed at secondary school students on clean energy access for cooking as part of their curriculum, or develop educational programmes to raise awareness of the negative effects of using dirty fuels, particularly among women who do the majority of household chores. Furthermore, the government could allocate more funds to develop infrastructure facilities to improve basic water and sanitation facilities, or it could provide subsidies for the purchase of efficient cookstoves and modern cooking technologies, thereby encouraging the use of clean fuel for cooking.

Applying the findings of Chapters 3 and 4, policymakers could include overseas inward migrant remittances as a means of reducing energy poverty and use remittances as a strategic tool in developing a financial, legal, and regulatory framework to achieve SDG 7. This can be accomplished through a variety of strategies: (1) strengthen the ability of the financial services sector to channel remittances into a variety of sustainable energy technologies, like fuel-efficient cooking appliances; (2) direct remittances towards energy development projects in rural areas, such as electrification and solar power; (3) provide incentives such as lowering the cost of remittance transactions or lowering taxes on modern cooking equipment for migrant families to invest in modern cooking methods and technologies; and (4) reduce the cost of energy access by introducing progressive tax rates. Chapter 4 also found that income inequality increases energy poverty. This shows an apparent link between energy poverty (SDG 7) and income inequality (SDG 10). This finding offers new policy insights for integrating various cross-sectional programs for energy and income inequality.

Finally, in order to address the long-term energy crisis, Sri Lanka should switch to renewable energy sources such as solar or wind power, as the country has plenty of sunlight and wind. This type of resilient clean energy network would help to protect the economy from external shocks. Policies have been implemented to transition Sri Lanka to carbon neutrality and 100% renewable energy generation by 2050, and these policies should be accelerated to meet the SDGs as expected. The use of renewable energy has a positive impact on the current account and balance of payment balances, resulting in an appreciation of the exchange rate. This will reduce inflation and raise people's real incomes, allowing the majority to meet their basic needs. The country's prevailing crises will be resolved by improving peoples' standards of living and well-being. The use of renewable energy will contribute to the reduction of energy poverty in the country, allowing the achievement of SDG 7.

6.2 Limitations and Future Research

Although this thesis used a large, nationally representative data set, some of the key variables influencing the choice of cooking fuel, such as fuel prices, were not included in our current research due to data availability. Furthermore, due to a lack of data and to gain a deeper understanding of their linkages, the analysis of synergies and trade-offs was limited to SDGs 4, 6, and 7, but the analysis could be extended to many other SDGs. Although this thesis has examined the impact of migrant remittances in monetary terms, further studies could go beyond that to examine how migrants' knowledge, skills, and experience in the destination country influence their decisions to use clean fuel for cooking. Future research could include these factors for a better understanding of the determinants of cooking fuel choice and how migrant remittances affect it.

Finally, some contemporary issues influencing energy poverty, such as the impact of COVID-19, were not included in this thesis due to data unavailability. COVID-19 has significantly affected migrant remittances, income inequality, energy poverty, and SDG achievement in most LMICs, including Sri Lanka. Researchers will be able to address these concerns in the future.

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6.4 Appendix

Co-Authourship Forms

Co-authourship forms are attached in the following pages.

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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 2: "Clean energy, clean water, and quality education: Prospects of achieving Sustainable Development Goals (SDGs) in Sri Lanka" is published at "Natural Resources Forum".

For Citation
Wijayarathne, J. M. D. S., Hassan, G. M., & Holmes, M. J. (2023). Clean energy, clean water, and quality education: Prospects of achieving Sustainable Development Goals (SDGs) in Sri Lanka. Natural Resources Forum, 1– 22. https://doi.org/10.1111/1477-8947.12287

Nature of contribution by PhD candidate	Conceptualizing the study, designing the empirical methodology, collecting, cleaning, analyzing data, producing, and revising the paper, finalizing, and submitting the paper.
Extent of contribution by PhD candidate (%)	70

CO-AUTHORS

Name	Nature of Contribution
Gazi Hassan	Provide guidance, review, and provide critical feedback on paper's structure, methodology, analysis, results and interpretations, revise and edit the draft, advice and submit the paper to the journals and address the feedback of journals.
Mark Holmes	Provide constructive feedback to improve the paper, proof reading, and offer advice on submitting the paper to the right journal.

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
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Chapter 3: "Migration, Remittances and Clean Fuel Usage in Sri Lanka: Exploring the Mediating Role of Household Wealth" is under review at Journal of Applied Economics

Nature of contribution by PhD candidate	Conceptualizing the study, designing the empirical methodology, collecting, cleaning, analyzing data, producing, and revising the paper, finalizing and submitting the paper.
Extent of contribution by PhD candidate (%)	70

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Gazi Hassan	Provide guidance, review, and provide critical feedback on paper's structure, methodology, analysis, results and interpretations, revise and edit the draft, advice and submit the paper to the journals and address the feedback of journals.
Mark Holmes	Provide constructive feedback to improve the paper, proof reading, and offer advice on submitting the paper to the right journal.

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Chapter 4: "Migrant Remittances, Income Inequality and Energy Poverty: A Pseudo Panel Approach" is under review at Journal of Resources & Energy Economics.

Nature of contribution by PhD candidate	Conceptualizing the study, designing the empirical methodology, collecting, cleaning, analyzing data, producing, and revising the paper, finalizing and submitting the paper.
Extent of contribution by PhD candidate (%)	70

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Chapter 5: "Covid-19, Energy Crisis and Sri Lankan Economy: A Matter of Migrant Remittances?" is under review at Journal of Energy Policy.

Nature of contribution by PhD candidate	Conceptualizing the study, producing, and revising the paper, finalizing, and submitting the paper.
Extent of contribution by PhD candidate (%)	70

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