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Vietnam between economic growth and ethnic divergence: A LASSO examination of income-mediated energy consumption

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ABSTRACT

Ethnic divergence in energy consumption is a phenomenon that threatens the potential gain in welfare that developing countries can achieve with strong economic growth and rise in income. However, the underlying mechanism preventing ethnic groups from accomplishing a successful transition to modern fuels is not yet well-understood, requiring an in-depth analysis of interaction effects between ethnicity and rise in income. The case of highly ethnically-diverse Vietnam offers an opportunity to examine the role of race on energy transition at the stage when grid electricity is available and income begins to rise. A methodological framework exposes the direct effect of ethnicity as well as the indirect, income-related effect of ethnicity on the ability of rural households to increase their electricity consumption. Using data from Vietnam's 2010 Household Living Standards Survey, feature selection is conducted with a machine learning technique, the *least absolute shrinkage and selection operator* (LASSO), which allows building robust models in the context of high-dimensionality. Furthermore, a mediation analysis complemented with a non-parametric bootstrap approach shows that income acts as a full mediator of ethnicity with respect to electricity consumption and as partial mediator for electricity expenditure. The results thus reveal a positive interaction effect between income and ethnicity, indicating different effects of rising incomes for Kinh and non-Kinh households, where Kinh are more likely than non-Kinh to translate extra income in higher electricity usage. Our results highlight the immanent need to identify and address non-income barriers that create ethnic disparities in the ability of poor, rural households to increase electricity use.

1. Introduction

Access to energy is an essential part of improving livelihoods in developing countries and is recognized by the seventh sustainable development goal (SDG) of the United Nations. In particular, SDG 7.1 emphasizes a primary reliance on *clean* fuels and technology, such as electricity and natural gas, which have lower carbon emissions than traditional biomass and solid fuels (e.g. coal). Transition to clean fuels has major benefits for the health of individuals: household indoor air pollution from solid fuels was one of the three leading risk factors for global disease burden in 2010, according to Lim et al. (2012). Burning traditional fuels also has consequences on deforestation of certain areas and global warming (Masera et al., 2015). Given the recent progress in rural electrification (almost 100% households are now connected to an electricity source in India, China, Vietnam…), literature in this domain now aims to identify where lie other obstacles to transition, for example hours of electricity supply available per day and its affordability for poor households (Agarwal et al., 2020; Wang et al., 2021b). In addition, the field of energy justice identifies that some population groups bear an unequitable burden of energy use and are not able to operate in the energy transition (Jenkins et al., 2016; Reames, 2016). It is therefore of particular importance to support sub-populations in their transition process towards modern energy usage and reduce reliance on coal and biomass. The present study aims to examine specific barriers which prevent the much-needed transition to electricity for socially disadvantaged groups, in particular the interaction of ethnicity with the major determinant of electricity use: household resources.

Income has been mapped out as one of the main drivers for successful transition, indicating that rising income accelerates the transition process towards modern energy sources (Barnes and Qian, 1992; Dowd, 1989; Fitzgerald et al., 1990). However, additional factors have been highlighted in the literature that influence fuel choices, such as sparse awareness and lack of familiarity with electricity (Bernard, 2012; Ranganathan, 1993), bureaucratic obstacles or unstable grid connection and reliability (Lee et al., 2016), as well as the impact of neighbors' responsiveness and adaptation to the electric grid (Bernard and Torero,

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2015). As a result, access barriers that prevent households from realizing their transition emerge, even if income is rising (Gertler et al., 2016). Furthermore, a persistent ethnic divide in many countries represents a major source of marginalization and discrimination with respect to access to economic opportunities (Heath and Cheung, 2007). Yet, aspects of ethnicity and race impacting upon a comprehensive household transition process have been so far neglected in the literature.

Since the early 1990s, Vietnam experienced dynamic economic growth with annual GDP growth rates around 6% (World Bank, 2021), accompanied by a fast-increasing electricity demand. Production capacities and investment in infrastructure were developed to meet the growing electricity demand. As a consequence, around 95% of all rural households are technically in condition to access the electric grid (Nguyen et al., 2019) and electricity access in rural areas is generally better than for other utilities (Dang, 2012). However, high electrification rates and economic growth do not guarantee homogenous electricity consumption for all Vietnamese households. Energy costs have risen more than income in Vietnam, especially for low-income deciles (Nguyen et al., 2019). Consequently, poor households have been exposed to higher energy expenses, resulting in increased access barriers to modern energy sources. Furthermore, additional mechanisms seem to be at work, which condition energy poverty. In particular, Nguyen et al. (2019) show that it is predominantly ethnic minorities that are subject to energy poverty. Over the period between 2004 and 2016, most Vietnamese households successfully transitioned to modern fuels owed to their improved economic status. However, the observed trend did not apply to the poor and ethnic minorities, for whom benefits of improved access to electricity were cancelled out by energy expenditures (driven by coal) increasing faster than income over the same period. Inequalities with regards to energy consequently increased. However, the underlying reasons for a slower transition process compared to the dominant ethnic group remain uncertain. Clearly, the persistence of energy poverty among ethnic groups calls for a closer look at the mechanisms and determinants of electricity usage across social groups.

Given that income is one of the main determinants of energy transition and electricity usage in the developing world (Gertler et al., 2016; Mcneil and Letschert, 2010), and that Vietnam benefits from substantial economic growth and good infrastructure coverage, further examination of the role of income in relation to the persistent racial electricity usage divide is required. Looking beyond mere electricity connection, the present study uses data from the 2010 Vietnam's Household Living Standards Survey to understand the interaction between rising income and racial determinants, in order to identify the barriers that may prevent ethnic minorities from transitioning to higher electricity consumption in Vietnam.

Consequently, this paper contributes to an improved understanding of electricity consumption of ethnic minorities in three ways. Firstly, electricity consumption and more generally energy poverty have been framed as multidimensional phenomenon that is linked to a great number of socio-economic determinants. In order to reduce the dependence of the results on many predictors, we aim to build a parsimonious model where only the most important determinants are selected, by using the data-driven process *least absolute shrinkage and selection operator* (LASSO), a machine learning technique. This process reduces variance and allows the model to match more closely the context of this study. Secondly, we confirm that rising household income is a valid channel of racial distinction using, inter alia, the mediation approach by Baron and Kenny (1986). Finally, the inclusion of an interaction term between ethnicity and income in the empirical approach quantifies the different effect of increasing income on electricity consumption for majority and minorities.

2. Background

2.1. Ethnicity-related issues in Vietnam

According to the Minority Rights Group International and based on 2009 census data, ethnic composition in Vietnam is primarily driven by the ethnic Viet or Kinh, which represent 85.7% of the total population. Besides, main minorities in the country are Tay, Thai, Muong, Khmer Krom, Hmong, Nung and Hoa, all at least representing 1% of the total population (Minority Rights Group International, 2018). Up to 54 diverse ethnic groups are recognized, but ethnic minorities are strongly associated with poverty and considered to be traditionally backward by the authorities (Taylor, 2008). On the contrary, individuals belonging to the majority group hold both economic and political power over the country and count with a considerably advantageous position to access infrastructure or institutions (Imai et al., 2011). This also reflects in poverty rates, affecting minority groups over-proportionally hard compared to members of the majority group (Dang, 2012), but also shows in gaps related to life expectancy, health and nutrition outcomes as well as living standards (Pham Thai et al., 2010; Mbuya et al., 2019), or credit and consumption (Nguyen et al., 2020). Although considerable advances have been made in terms of poverty reduction, ethnic minorities still represent more than half of the total poor in Vietnam (Pham Thai et al., 2010). What is more, it is predominantly members of the majority ethnic group that benefited from economic growth while the share of ethnic minorities in the poor population has been constantly growing since the early 1990s.

The government has not been inactive in the matter and programs that support ethnic minorities in many domains were implemented (Dang, 2012), such as the Ethnic Minority Planning Framework (Electricity of Vietnam, Power Design Center, 2005) and others. However, policy implementations that aimed to target minority groups did, in most cases, not achieve their aim. Between 1993 and 2004, an increasing gap of 14.6% of real expenditure was recorded (Baulch et al., 2012). On that account, Pham Thai et al. (2010) stress that uniform approaches and policies were not adequate in addressing poverty outcomes in Vietnam. Minority groups did not benefit from past governmental interventions to the same degree as individuals of the majority group did. Using data from 1998, Baulch et al., 2008 testify considerable differences in standards of living between Kinh and non-Kinh households, which continue to persist.

Consequently, Van de Walle and Gunewardena (2001) investigate underlying mechanisms that determine ethnic disparities in Vietnam. Minority groups are primarily located in remote, mountainous areas and suffer from insufficient public service provision and infrastructure, but it is predominantly returns to productive factors that shape ethnic disparities. Minorities are often found in areas that are less productive, harder to cultivate, far away from major markets including non-agricultural labor markets, and areas scarce in public service provision. Furthermore, members of minority groups face adverse effects of lower returns to education and land, not only due to their remote location but also because of their socio-economic status as minority. In other words, the authors find evidence for ethnic divergences in Vietnam both because of a geographic factor of influence as well as socio-economic differences (Van de Walle and Gunewardena, 2001). Singhal and Beck, 2015 further focus attention on divergent origins of household income, with non-Kinh members being less likely to occupy well-paid, non-agricultural positions. Similar results are reported by Imai et al. (2011), who confirm mitigated returns both to education and land for members of minority groups (see also Baulch et al., 2008). Further, Mbuya et al. (2019) identify low coverage of government programs among ethnic groups as a reason for persisting differences in malnutrition between dominant and minority groups. Poor accessibility (topology of terrain dominated by hills and mountains) as well as language and culture barriers, which lower trust towards governmental institutions and thus reduce participation in programs, can all explain lower program coverage. Besides, remoteness contributes to reduced awareness and only limited knowledge diffusion about existing support programs amplify the problematic (Dang, 2012). In addition, Thanh Tung Nguyen et al. (2020) point out difficulties in accessing formal credit, suggesting reduced financial integration of minority groups into the formal economy. In relation to energy, Feeny et al. (2021) identify that the over-reliance on agricultural income of the central and northern regions and the vulnerability of crop yields to extreme climate events, such as heat waves, reinforce the propensity towards energy poverty of mentioned regions, which are mainly populated by ethnic groups and dominated by agriculture livelihood.

Overall, the effects of poverty and low income on diverse human development outcomes have been vastly investigated (Anand and Sen, 1997; Arimah, 2004), and the link between ethnicity and poverty has attracted major scholarly attention (Awaworyi Churchill and Smyth, 2017; Gang et al., 2002). In line, Rafi et al. (2021) demonstrated how being energy poor impacts adversely upon multiple human capital outcomes, such as for example increased likelihood of severe diseases, malnutrition, lower school enrollment rates or human capital formation. Yet, only limited research has been conducted on the relationship between ethnicity and energy poverty. Nevertheless, the next section shows that ethnic differences in electricity usage are not limited to the context of Vietnam or to developing countries, but are rather widespread, which calls for consistent and research-based policy action.

2.2. Ethnicity and energy in other countries

In Australia, greater ethnic diversity at the neighborhood level, measured inter alia by the Herfindahl's index, is associated with increased energy poverty. In particular, the share of household income spent on energy, as well as on the number of households spending >10% of their income on energy is greatly driven by ethnicity (Churchill and Smyth, 2020).

Similarly, in the US, great heterogeneity - racial, social and geographical - is observed for energy consumption and energy poverty patterns. African-American households are more prone to suffer from energy poverty (about one-third of them) than White or Asian households, with little observed variability over the past 25 years, except from an increasing share of energy poor White households between 1990 and 2015 (Wang et al., 2021a).

Energy poverty is also strongly prevalent among marginalized groups of the highly hierarchical society of India (Acharya and Sadath, 2017). Sedai et al. (2021) capture specificities of energy poverty in a developing country context, where electricity usage depends on infrastructure such as access to the grid connection, but also on sufficient hours of power supplied each day. With data for 2005 and 2012, they find that marginalized groups (Hindu Schedule Caste/Schedule Tribe and Muslims) were less likely than ethnically dominant groups (Hindu of other casts) to have had an electricity connection in the past. However, disadvantaged groups in India enjoyed a higher likelihood of electricity access in 2012 as well as a better reliability of electricity supply in terms of hours of electricity per day. This renders evidence for a positive effect of public policies to reduce the social gap, with an accelerated access rate for disadvantaged groups during the period of an intense rural electrification program. However, the authors found that the welfare effect of improved electricity access, although positive, was not as strong for socially marginalized groups as it was for dominant groups. For example, better electricity is associated with increased income, larger assets, and moving out of poverty, but the observed effect was smaller than for the dominant group. This indicates that other barriers come into play concerning the reduction of welfare disparities across communities. Consequently, this work is a step forward, pointing out that policies may not have the same effect on various socio-economic groups, but that existing social discrimination, here via the factors of religion and social status (caste), are not immutable.

In contrast, Pelz et al. (2021) find that for 6 North Indian states, inequalities of grid connection between Schedule Caste/Schedule Tribe and dominant groups remained constant from 2015 to 2018, while improvements in the quality of power (daily hours of power and monthly power outages) were lower among minorities than for the dominant group. This indicates that changes may not have been robust over time and region. For the case of Sri Lanka, higher multidimensional energy poverty rates are found among Tamils, who represent about 22% of the sample, than among Sinhalese, who form about 77% of the sample population (Jayasinghe et al., 2021). In Nepal as well, ethnic fractionalization is associated with more severe energy poverty, which particularly affects low-caste individuals (Paudel, 2021). Significant disparities based on race are also found for South Africa where people of African descent face higher energy poverty levels than people of White or Asian/Indian descent (Ismail and Khembo, 2015).

Clearly, members of ethnic minorities routinely experience strong difficulties concerning the access and availability of electricity compared to majority groups. In order for policy makers to address these discriminations, the mechanisms through which race affects energy usage must be identified.

2.3. Channels of explanations for ethnic disparities

Ethnicity can drive energy poverty via several channels. In the context of developed countries, where energy poverty is mostly characterized by high prices and low income, Churchill and Smyth (2020) provide a conceptual framework that identifies trust as a possible link between energy poverty and ethnic diversity. First, different environmental values may lead to diverging practices with respect to, for example, insulating homes. Second, ethnic minorities experience lower income due to rent-seeking behavior, which is more prevalent in ethnically diverse societies, or due to the lack of opportunities and discrimination on the job market. Third, lack of trust towards ethnic communities may result in weaker infrastructure or hinder the delivery of public goods, and thus lead to higher energy prices. Finally, the authors show that trust at the neighborhood level is more important than income to explain higher energy poverty levels for more ethnically diverse neighborhoods. Similarly, long-lasting mistrust between policy makers and marginalized communities of Bedouin (Israel) and Roms (Romania) is pointed out as a decisive factor in persisting energy poverty experienced by these communities, together with a lack of interest by policy makers and a general level of informality adopted by these communities (Teschner et al., 2020).

In this context, Aklin et al. (2021) highlight that the social bias of the local implementation officers, mainly belonging to dominant groups, against discriminated communities in India can explain the poor, local implementation of the program. Indeed, they find that a high proportion of the socially-discounted scheduled castes at village level in India decreases the probability of receiving support from the government-led electrification program RGGVY (Rajiv Gandhi Grameen Vidyutikaran Yojana).

In contrast to these human-based factors, some racial disparities seem to be rooted in more technical aspects of energy usage. Brockway et al. (2021) highlight how technical capacities of the grid to accommodate the distribution of solar energy generation can be a vector of racial discrimination. The authors show that the ability of local residents to adopt solar photovoltaic systems is highly limited for racially and socially disadvantaged groups because of racial patterns in the grid construction. Therefore, the concerned households miss out on the opportunity offered by solar photovoltaic systems to lower electricity expenditure.

Continuing with material characteristics, the higher energy burden experienced by African-American households is mainly due to poor energy efficiency performance of their dwellings (Drehobl and Ross, 2016). In particular, African-American and Hispanic households are more vulnerable to fuel poverty because urban housing patterns reflect persistent racial segregation in access to housing. The housing stock these households generally occupy is among the least energy efficient (Reames, 2016). Low energy efficiency coupled with lower income are thus causes of higher energy poverty for socially-disadvantaged groups in the US.

Therefore, racial differences in access to modern energy can clearly result from institutional frameworks and patterns (trust, representation, housing discrimination). However, no study has so far examined how income, the main driver of energy transition in developing countries, contributes to ethnic divergences in relation to energy, on top of the known racial discriminations related to income.

2.4. The role of income in energy transition

Authors such as Leach (1992), Smith (1987) describe the transition mechanism as a ladder. In the ladder theory, energy demand is assumed to be initially met by firewood. In a next step, the supply constantly decreases due to deforestation activities, resulting in the substitution of wood by charcoal and kerosene. Lastly, the transition process profits from evolving energy markets, which provide newly industrialized and urban areas with electricity. For Barnes et al. (2004, p. 22) income is a key driver in the energy transition process. Importantly, it is firstly urban zones that undergo mentioned transition process while rural areas often lack necessary income requirements to keep pace with the development process (Barnes et al., 2004, p.22). Leach (1992) and other studies (Hanna and Oliva, 2015; Hosier and Dowd, 1987; Van der Kroon et al., 2013) also link the transition towards modern energy sources to key components of economic development and growth. With an accelerating development process and increasing urbanization, the average income level is expected to increase and hence facilitate the transition towards modern energy sources, predominantly in urban areas. In practice however, households have been found to adopt fuel stacking, i.e. they continue using multiple fuel sources simultaneously as they climb the energy ladder, before they can fully transition (Choumert-Nkolo et al., 2019), but this process is also driven by income.

All in all, income remains an important factor that determines households' transition to electricity in developing countries. With rising available income, a surge in energy consumption follows (Sari and Soytas, 2007). McNeil and Letschert (2010) describe household's energy transition process as a function of income following a S-shaped curve. Based on a theoretical framework developed by Gertler et al. (2016), it is also income that drives energy consumption in developing countries. In their framework, the authors describe the impact of economic growth in the developing world, resulting in rising income, on shifting demand patterns for energy. Once households pass a critical point in available income, a process of energy-using acquisition of durable consumer goods is initiated. These so-called "first-time owners of energy-using assets" (Gertler et al., 2016; p. 1398) are those that drive the energy transition process in the developing world.

Empirically, Pachauri and Jiang (2008) investigate the case of India and China, where they particularly highlight the persistence of major gaps in electricity access between urban and rural households for both country cases (see also Dong and Hao (2018) for China). On that account, it is still primarily rural areas that rely heavily on traditional energy sources and hence rarely consume commercial energy. Main reasons for a decelerated rural household energy transition are considerably lower income levels resulting in divergent spending preferences, higher energy prices compared to urban areas and inferior energy supply, which is often unreliable and unstable, as well as higher opportunity costs with regards to traditional fuel sources (Pachauri and Jiang, 2008). Income inequality between Chinese urban and rural areas thus translates into considerably lower per capita energy consumption in rural areas than in urban ones (Dong and Hao, 2018). Similarly, Louw et al. (2008) emphasize the role of income for energy demand in the context of African households with weak economic resources.

Additionally, Han et al. (2018) claim, investigating the case of China, that it is not only income that determines the pace of rural energy transition, but factors such as the size of the household, the educational level of the head as well as the number of available electronic appliances that significantly determining the speed and mode of transition. This is in line with the assumption that the ability of transitioning from energy poverty to an electricity-dominated consumption is a multidimensional approach, with determinants that include household characteristics, habits and fuel choices as well as results of public policies for access to market and affordability (Nussbaumer et al., 2012; Ashagidigbi et al., 2020; Jayasinghe et al., 2021; Mendoza et al., 2019; Nussbaumer et al., 2013; Sadath and Acharya, 2017, and others). In line, Nguyen et al. (2019) therefore conclude that economic development and the speed of transition are linked with each other, conditioning the nature of the energy transition process.

In addition, income is identified as a channel through which other factors may influence energy poverty and electricity usage. In this context, Cheng et al. (2021) confirm that income is a channel through which children that experienced famine are less likely to suffer from energy poverty later in life. Similarly, Wang et al. (2021b) show that vulnerability to rain of agriculture-oriented communities is the most important predictor of energy poverty for North India, because rain is associated with rural incomes. In relation to ethnicity, income appears to be a mediating factor of severe energy poverty experienced by low-caste individuals in Nepal (Paudel, 2021). Thus, frictions based on ethnic association or household characteristics might also result in mitigated energy consumption that are channeled through income. Consequently, rising household income acts as a mediator for energy consumption, contingent on ethnicity and socioeconomic background.

2.5. Ethnicity, income and electricity

The role of ethnicity on energy, as well as the importance of income in the context of energy transition, have been highlighted in the literature (see Ssections 2.3 and 2.4). However, the interdependence between the concepts of ethnicity, income and electricity usage has not yet been examined. Son and Yoon (2020) find a nonlinear role of income on electricity usage in Vietnam, which indicates unequal usage and uptake rates between households. What is more, the authors stress that despite low-income households having access to the grid in Vietnam, utilization is not proportional to income, resulting in higher inequality in the domain of energy than in the domain of income. In light of minority households composing a large share of the total poor in Vietnam (Pham Thai et al., 2010), the linkage between income, ethnicity and electricity needs to be further examined. As a matter of fact, energy costs have been rising faster than income has, exposing poor, rural and non-Kinh households to a higher risk of energy poverty (Nguyen et al., 2019).

On that account, the mechanisms both between income and electricity use (Pachauri and Jiang, 2008; Barnes et al., 2004; Han et al., 2018) and between ethnicity and poverty (Imai et al., 2011; Dang, 2012; Pham Thai et al., 2010) appear to be well understood, whereupon the nexus between ethnicity, income and electricity is not yet clearly established in the literature. Therefore, the present study fills in upon the unveiled research gap and investigates differential effects of rising income on electricity usage between majority and minority households. The mechanism of effect aims to capture the transitioning process of continuous economic development taking place in Vietnam, which translates into rising household income. Income growth, in turn, results in divergent electricity usage rates between households of the majority and minority group and is thus subject to this study. The design of the research represents a novel approach within the field of energy poverty and energy inequality, by developing a framework that can explicitly capture both the direct and indirect effect of ethnicity on energy, and quantify the role of growing income as a mediator in the relation. Our findings consequently provide insights for future policy designs that effectively aim to target heterogeneous population groups in Vietnam. Furthermore, the variable selection with the LASSO technique allows selecting the variables that contribute the most to the variance of the outcome in the applicable data.

3. Methodological framework

3.1. Base model

Electricity consumption and expenditure depend on a large number of determinants, among them income, energy prices and socio-economic factors. Given the evident ethnic differences in electricity usage in many countries as well as the established divergence in living standards between Kinh and non-Kinh households in Vietnam (Baulch et al., 2008; Baulch et al., 2012), a relationship between ethnicity and electricity appears to be consistent with the overall environment. However, additional socio-economic factors that are important concerning the energy behavior of households are likewise associated with race; primarily income, cultural habits and economic opportunities. In order to identify how ethnicity may be a barrier towards increased electricity usage and energy transition, the analysis aims to include both direct and indirect effects of ethnicity on electricity usage. Further, the study focuses solely on the indirect effect of ethnicity through income, as income is the main determinant of energy transition. Energy consumption q can be expressed as a function of the ethnic group the household belongs to k, income x, electricity prices p, as well as a vector D of additional covariates that will be selected by a data-driven process.

$$q = f(k, x, p, D)$$

Therefore, belonging to an ethnic minority is expected to have a direct effect on electricity consumption and expenditure. However, as ethnic minorities face disadvantages in other domains as well, it is clear that income is a function of ethnic belonging due to possible racial discriminations, such that:

$$x = x(k)$$

This in turn has implication for energy consumption. Thus, we pose that ethnic belonging also affects electricity consumption and expenditure indirectly through the channel of income. Therefore, to examine the marginal effect of ethnicity on electricity consumption and expenditure, both direct and indirect effects must be accounted for. Similar to the method in Sun et al. (2021), and assuming that prices and additional covariates D are exogenous to ethnicity, the total differentiation gives:

$$\frac{dq}{dk} = \left.\frac{\partial q}{\partial k}\right|_{Fixed\ x} + \left.\frac{\partial q}{\partial x}\right|_{Fixed\ k} . \frac{\partial x}{\partial k}$$

Where $\left.\frac{\partial q}{\partial k}\right|_{Fixed\ x}$ represents the direct effect of ethnicity on electricity while $\left.\frac{\partial q}{\partial x}\right|_{Fixed\ k} . \frac{\partial x}{\partial k}$ captures the indirect effect of ethnicities on electricity via the channel of income.

Applying a log transformation to income, the effect of ethnicity on the consumption of electricity can be estimated empirically with the following model, where an interaction term between ethnicity and income serves to capture the income effect of ethnicity on electricity usage:

$$q = \beta_0 + \beta_1 k + \beta_2 lnx + \beta_3 k.lnx + \sum_{i=4}^{j} \beta_i D_i \tag{1}$$

In order to grant robustness to the empirical analysis, two additional steps are performed prior the empirical estimation. First, the most relevant features to be used as controls in the estimation are identified and selected via the machine learning regularization process LASSO. Second, to verify the assumption that income is a valid channel for the effect of ethnicity on electricity consumption, a formal test of the mediation effect is employed. Additional details on these methodologies are provided below.

3.2. Feature selection with LASSO

Electricity usage is linked to a large set of determinants including socio-economic status of the households, demography of the household, electrical equipment, habits, or energy prices. However, not all determinants carry the same importance, and selecting the right set of controls is best achieved when context-specific information is accounted for. In such context of high dimensionality, the machine learning technique of *least absolute shrinkage and selection operator* (LASSO) provides a formal and efficient method for feature selection. The technique relies on the assumption of approximate sparsity of most models, which indicates that among the high number of regressors of a model, only some of them are relevant to capture the main features of the regression. This approach has already been used for the purpose of feature selection in predicting energy consumption in buildings (Jain et al., 2014), solar power generation (Tang et al., 2018) or human decision making towards energy usage (Das et al., 2019), among others. This form of feature selection was found to generate improved accuracy compared to conventional methods, henceforth, we employ it for the present research question.

Specifically, the LASSO approach is a regularization technique that aims to reduce the variance arising from the standard ordinary least squares (OLS) approach by introducing some bias in the coefficients (Lesmeister, 2015). To do so, the model not only minimizes the residual sum of squares (RSS), but also a penalty that consists of a tuning parameter lambda and the sum of absolute values of the coefficients β_i.

$$min\left(RSS + \lambda \sum \beta_i^{\,2}\right)$$

During the minimization process, lambda increases and the coefficients lower, so that the prediction becomes less sensitive to input values, thus diminishing the problem of over fitting and high variance. The process of lowering coefficients allows some coefficients to decrease to zero, an advantage which enables to drop variables with little explanatory power and limit the model to its most meaningful features.

The right dose of penalty is determined by the value lambda, comprised between 0 and 1, and is typically chosen via cross-validation. However, machine learning techniques are often criticized for lacking theoretical background. To remedy this, Chernozhukov et al. (2016) propose an improvement to the LASSO technique that relies on theoretically grounded data-driven choice of penalty level lambda, called the rigorous LASSO and implemented in the *'hdm'* package in R. Furthermore, in order to remove the potential bias created by shrinking the coefficients to zero, a post-LASSO estimator is used, that applies ordinary least squares to the data after removing the regressors that were not selected by the LASSO (Belloni and Chernozhukov, 2013).

3.3. Mediation effect

In this step, the validity of income as a mediation factor for ethnicity on electricity usage is determined. In the literature, the theoretical foundations of the mediation effect have been first summarized by Baron and Kenny (1986). Impacting upon the dependent variable, the mediator is assumed to alter the outcome through its influence on the independent variable. Central to the framework is the assumption of a mediation effect, which either reinforces or mitigates the strength of the effect of the independent variable on the dependent variable (Baron and Kenny, 1986). Accordingly, the authors define the role of the mediator as additional, explanatory component which investigates the underlying reason and mechanism of an observed effect (Baron and Kenny, 1986; Preacher and Hayes, 2004). In order to statistically test for and confirm the occurrence of a mediation effect, Baron and Kenny (1986) assume the absence of measurement errors concerning the mediator variable as well as the independence between independent variable and mediator. Further, the following three conditions need to hold:

- Firstly, when running a regression of the mediator (income) on the independent variable (ethnicity), a significant effect of the independent variable on the mediator needs to be established. Formally, the first condition can be expressed as:

$$ln\,\hat{x} = \alpha_1 + a\,k + \varepsilon_1$$

- Secondly, when running a regression of the dependent on the independent variable, a significant effect of the independent variable on the dependent variable needs to be established. The second condition is formally expressed as follows:

$$\hat{q} = \alpha_2 + b\,k + \varepsilon_2$$

- Lastly, when running a regression of the dependent variable on both the independent and the moderator variable, a significant effect of the meditator variable on the dependent variable needs to be established. Further, the effect of the independent on the dependent variable should be smaller in the last regression compared to the second model.

  Formally, the equation estimates:

$$\hat{q} = \alpha_3 + c\,k + d\,lnx + \varepsilon_3$$

where α_i represents the intercept, a, b,c and d are parameters that measure the strength of effect and ε_i represents the error term.

In this context, Preacher and Hayes (2004) advocate for formal statistical testing in order to confirm the presence of a mediation effect. Although both the methodology by Baron and Kenny (1986) as well as the Sobel (1982) are frequently used in the literature, they highlight potential limitations, which is in line with MacKinnon et al. (2002). The authors stress the reduced statistical power of Barron & Kenny's methodology compared to the Sobel test. The Sobel (1982) constitutes a statistical approach, testing the null hypothesis of an indirect effect of the mediator of zero magnitude. However, it assumes normal distribution of the sample as well as a large sample size, which is not always applicable to the underlying data sample (Preacher and Hayes, 2004). Formally, the Sobel test can be expressed as:

$$s_{cd} = \sqrt{c^2 s_d^2 + d^2 s_c^2 + s_d^2 s_c^2}$$

where s_{cd} represents the standard error of the indirect effect.

Testing for normal distribution of the dependent variables' electricity consumption and electricity expenditure in the last 12 months, we observe a non-parametric distribution of the variables of interest. To account for mentioned limitations of the structure of the data, a nonparametric bootstrap approach is additionally employed, which computes confidence intervals for the indirect effect and is not contingent on the distributional aspects of the underlying data structure (Preacher and Hayes, 2004; Tingley et al., 2014).

4. Empirical results

4.1. Data

The data employed in the analysis was extracted from the Vietnam's Household Living Standards Survey 2010. As established in the literature, the ethnic divide in living standards has not been subject to substantial changes over the years, but rather consists of a long-term phenomenon in Vietnam. Furthermore, energy use of minorities continues to be dominated by traditional energy sources, such as coal and biomass (Nguyen et al., 2019). Therefore, making use of the latest available cross-sectional data from 2010 is appropriate.

This biennially conducted survey covers 69.360 households distributed over 3.133 communes in Vietnam and is representative for the country's entire population at a national, regional, provincial, urban and rural stage (ILOSTAT, 2017). The design of the survey follows a three-stage stratified cluster based on enumeration areas defined for the 1999 Population and Housing Census (ILOSTAT, 2017). With the aim to evaluate differences in living standards and to improve the effectiveness of national programs to combat poverty and inequalities, interviews were conducted with the head of households as well as influential officials at the communal level.

In respect to electricity use, the nationally representative results of the survey show that 97.2% of households use grid electricity for lighting and that this share remains high in rural areas (96.2%) as well as among households of the lowest income quintile (91.6%), representing a constant improvement since 2002 (Vietnam General Statistics Officce, 2010). Among households of the Northern Midlands and Mountain areas, characterized by remote communities, the share of households using electricity lowers to 91.1%, and reaches its minimum at 83.8% in the specific Tây Bắc/ North West sub-region. Households which do not use grid electricity instead rely on electric generators or batteries as well as kerosene lamps for their lighting needs. The overall large share of population relying on electricity highlights the good infrastructure, since >98.9% of communes are connected to the grid through the national electricity network (Vietnam General Statistics Officce, 2010).

The analyzed sample consists of 82% Kinh households, Vietnam's largest and dominant ethnic group, while the remaining population is split between >50 ethnicities, each representing a small share of the population.[1] Preliminary summary statistics confirm that Kinh benefit from higher rates of connection to the national electric grid, as well as about twice the amount of consumption and expenditure on electricity compared to non-Kinh households.

Given the clear gap between urban and rural areas usage patterns of electricity, and that about 88% of non-Kinh live in rural areas, the analysis focuses on rural households only. The sample retained consists of 6373 rural households with a non-zero electric consumption, 18.8% of which belong to groups other than Kinh. The gap in electricity consumption between Kinh and non-Kinh is large (Fig. 1), and expenditure on electricity by Kinh is more than twice the amount spent by non-Kinh (Table 1).

4.2. Model selection

In order to select appropriate controls among the vast amount of information collected by the survey, LASSO regression is used (employing both rigorous LASSO and post-LASSO estimator, see section 3.1) for both outcomes 'electricity consumption in kWh per capita in the last month', and 'electricity expenditure over the last 12 months'. Table 2 provides summary statistics for the 36 variables that are initially included in the LASSO regression, which consist of socio-economic and demographic characteristics, as well as variables on education, equipment, dwelling size, energy prices, and location in remote area.

Table 3 shows the variables as identified by LASSO that contribute the most to the variance of each outcome. The models selected respectively 9 and 15 out of the 36 explanatory variables. Second, both models are found to have joint significance of the coefficients, as the null hypothesis, tested with a sup-score statistic (Chernozhukov et al., 2016), is rejected in both cases. The R-squared adjusted values reach 0.3 and 0.5 for each outcome respectively.

As expected, income is found to be a good predictor for electricity consumption and expenditure, as well as related sources to income (regular wage, business activity, own production). Further, the total

[1] Sample observations by ethnicity: Kinh, 82.2%; Tay, 3.5%; Thai, 2.5%; Chinese, 0.8%; Khmer, 1.6%; Muong, 1.4%; Nung, 1.6%; Hmong, 1.4%; Dao, 1.2%. This matches the national estimates.

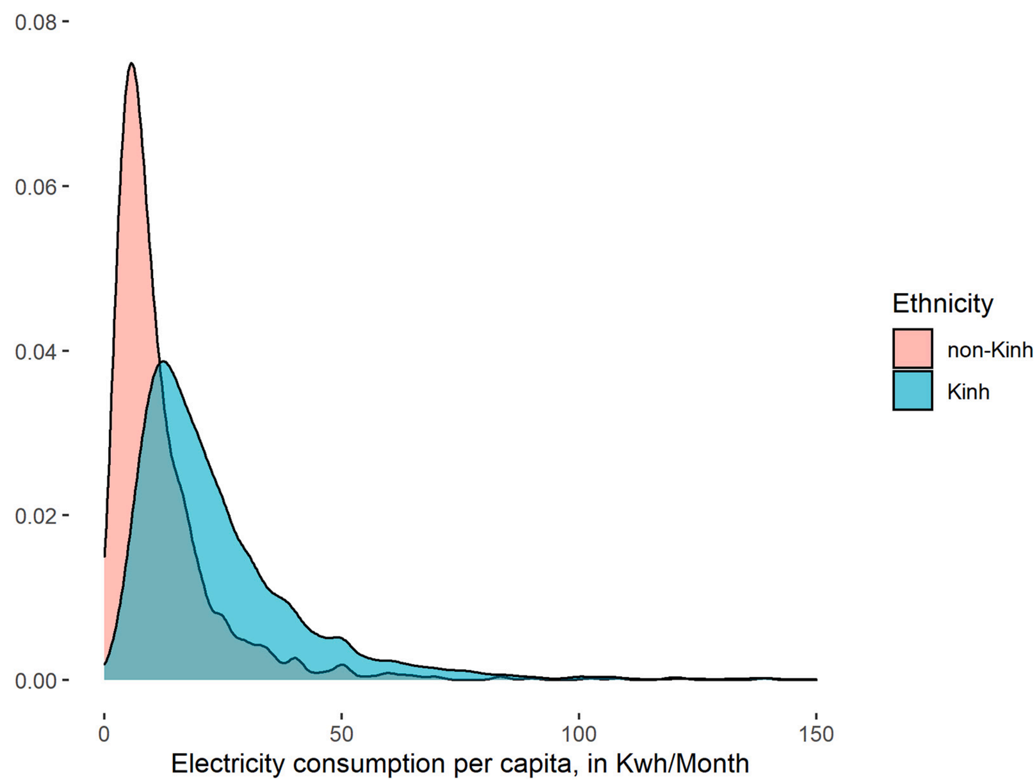

Fig. 1. Density of electricity consumption by ethnic groups, 2010, rural sample.

Table 1
Electricity usage and socio-economic indicator for rural households.

	Non-Kinh	Kinh
Electricity		
Consumption, last month, per capita, in kWh	12.7	24.8
Expenditure, last month, per capita, in thousand Dong	9.9	22.0
Expenditure, last 12 months, per capita, in thousand Dong	110.7	254.6
Household characteristics		
Yearly real consumption, per capita, in thousand Dong	8266	14,948
Household size	4.5	3.8
Illiteracy rate	0.20	0.32

$n = 6373$.

number of appliances owned by the households, as well as ownership of large appliances (fridge, air conditioning, and washing machine), are found to be important predictors for electricity consumption and expenditure. Ownership of small appliances however is not found to have sufficient association with electricity consumption and expenditure. Among socio-economic variables, it is not surprising to find that household size is selected by the LASSO approach as it has often been associated with energy consumption (Ozughalu and Ogwumike, 2019; Sharma et al., 2019; Wang et al., 2021b). However, education, gender, age, marital status and other measures of family structure such as presence of young or older dependents do not appear to have sufficient predictive power to be retained in the selected models. Electricity prices have a sufficiently strong association with both consumption and expenditure to be included in the reduced models. Regarding areas with higher shares of ethnic minorities, being located in the Central Highlands is not selected by the model, while being located in the Midlands and Northern Mountainous areas is found to have sufficient explanatory power for electricity expenditure, but not for consumption.

The coefficients also adopt the expected signs, with higher electricity consumption and expenditure being associated with higher income, ownership of appliances as well as larger dwelling. At the same time, income generation from household production, poverty status and dwelling in the Midlands and Northern Mountainous areas are associated with lower electricity consumption and/or expenditure. Electricity prices tend to reduce consumption while at the same time increase expenditure. Surprisingly, drawing income from a regular wage is associated with lower consumption. The effect of family size lowers consumption per capita but increases expenditure (measured at the household level).

4.3. Mediation through income

Next, a mediation analysis, as employed in previous studies (Alesina and Zhuravskaya, 2011; Cheng et al., 2021; Churchill and Smyth, 2020), helps verify the validity of income as a channel of racial differences on both electricity consumption and electricity expenditure.

Consolidating statistical results of the mediation analysis, the effect of income as a significant channel on electricity consumption is confirmed. Our results are consequently in line with theoretical considerations in the literature (Sari and Soytas, 2007; Mcneil and Letschert, 2010; Chang, 2015; Gertler et al., 2016). Assessing results that follow the approach by Baron and Kenny (1986), we observe a positive impact of being a member of the majority ethnicity on income by a factor of 0.6 (Table 4, Panel A). Besides, the effect of majority ethnicity on electricity consumption is statistically significant, indicating increased electricity consumption by 12.05 kWh per month of the Kinh minority. When additionally including income into the third equation, the ethnicity term becomes insignificant, yet, a substantial increase in electricity consumption with raising income can be observed. On that account, the effect of ethnicity on the dependent variable electricity consumption is larger in the third equation than in the second, which is in line with Baron and Kenny (1986). When including control variables into our equations, the observed effects still hold, albeit decrease in magnitude. Following this, we can observe a mediation effect of income on ethnicity, as shown in Fig. 2. The slope for electricity consumption for

Table 2
List of variables included in the LASSO model.

Variable	Description	Mean	Std. Dev.	Min	Max
Outcomes					
Electricity consumption	Continuous: consumption of electricity per capita last month, in kWh	22.52	23.32	0.273	425
Electricity expenditure	Continuous: expenditure on electricity over the last 12 months, in thousand Vietnamese Dong	820.38	794.15	0	13,740
Determinants					
Income	Continuous: log of monthly real consumption per capita, in thousand Vietnamese Dong	9.35	0.57	7.35	12.53
Female	Binary: Gender of the household head, 1 if female, 0 if male	0.21	0.40	0	1
Married	Binary: Marital status of the household head, 1 if married, 0 if not	0.83	0.37	0	1
Age	Continuous: age of the household head in years	48	14	11	99
Low secondary	Binary: the household head completed lower secondary school as maximum education, 1 if yes, 0 if no	0.30	0.45	0	1
High secondary	Binary: the household head completed higher secondary school as maximum education, 1 if yes, 0 if no	0.11	0.31	0	1
College	Binary: the household head completed college or undergraduate as maximum education, 1 if yes, 0 if no	0.02	0.15	0	1
Graduate	Binary: the household head completed graduate school as maximum education, 1 if yes, 0 if no	0.00	0.03	0	1
Household size	Continuous: total number of members in the household	3.95	1.57	1	15
Number children	Continuous: Number of children below 6 years old in the household	0.38	0.61	0	4
Children	Binary: Presence of children under 6 years old, 1 if yes, 0 if no	0.31	0.46	0	1
Number aged members	Continuous: Number of adults above 65 years old in the household	0.26	0.54	0	3
Dependent	Binary: Presence of adult above 65 years old, 1 if yes, 0 if no	0.20	0.40	0	1
Wage	Binary: Someone in the household receives a wage or salary, 1 if yes, 0 if no	0.62	0.48	0	1
Wage 2	Binary: 2 or more persons in the household receive a wage or salary, 1 if yes, 0 if no	0.29	0.45	0	1
Household production	Binary: Someone in the household is self-employed in agriculture, 1 for yes, 0 for no	0.80	0.39	0	1
Household production 2	Binary: 2 or more persons in the household are self-employed in agriculture, 1 for yes, 0 for no	0.62	0.48	0	1
Business	Binary: Someone in the household is engaged in trade or business, 1 for yes, 0 for no	0.31	0.46	0	1
Business 2	Binary: 2 or more persons in the household are engaged in trade or business, 1 for yes, 0 for no	0.14	0.34	0	1
Poverty status	Binary: the household was classified as a poor one of the commune/ward, 1 for yes, 0 for no.	0.13	0.33	0	1
Kerosene expenditure	Continuous: Expenditure on kerosene last month, in thousand Vietnamese Dong	1758	236	0	43,200
Squared meters	Continuous: indicates the size of the dwelling	66.14	38.05	4	410
Number appliances	Continuous: Number of appliances owned by the household	4.58	2.65	0	23
Fridge	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.29	0.45	0	1
Television	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.83	0.38	0	1
Air conditioning	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.02	0.122	0	1
Washing machine	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.07	0.24	0	1
Electric fan	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.75	0.43	0	1
Electric cooker	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.66	0.47	0	1
Heavy machine (electric generator, pumping machine)	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.42	0.49	0	1
Music or video (radio cassette player, disk player)	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.56	0.49	0	1
Computer	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.08	0.26	0	1
Office equipment (landline, fax, printer)	Binary: Ownership of specific electric appliances, 1 for yes, 0 for no	0.29	0.45	0	1
Electricity price	Continuous: price calculated as the expenditure per capita last month over the consumption per capita last month	0.95	0.79	0	11.66
Northern	Binary: The household is located in Midlands or Northern Mountainous areas, 1 for yes, 0 for no	0.18	0.38	0	1
Central	Binary: The household is located in the Central Highlands, 1 for yes, 0 for no	0.07	0.25	0	1

members of the majority ethnicity is steeper compared to their non-Kinh counterparts, indicating a faster uptake in electricity consumption with raising income. This confirms the assumption of divergent electricity consumption patterns among Vietnamese ethnicities.

Running a Sobel test yields insignificant results with a *p*-value of 2.98. However, the dependent variable electricity consumption is not normally distributed, which is why we additionally employ a non-parametric bootstrap approach. The results confirm the mediating effect of income as a channel on electricity consumption. With a total effect of 240.89 kWh, ethnicity significantly affects electricity consumption. Since the direct effect (Average Direct Effect) is insignificant, we assume full mediation. In other words, the effect of ethnicity on electricity consumption is fully explained by income, with a significant average causal mediation effect, or indirect effect, of 204.7 kWh. Further, if electricity consumption was only determined by income – conditional on ethnicity - household would experience a remarkable rise in electricity demand. However, it seems reasonable to assume that additional covariates impact upon electricity consumption. When including control variables into the model, the full mediation effect still holds but greatly decreases in magnitude. The indirect effect of income consequently results in an increased electricity consumption of 39.27 kWh.

Similarly, income is a channel that impacts upon electricity expenditure. Evaluating the conditions established by Baron and Kenny (1986), we observe a small but positive effect of belonging to the majority group on income (Table 4, panel B). Likewise, the impact of ethnicity on electricity expenditure is positive for members of the majority group by a factor of 466.88 (measured in Thousand Dongs). Expenditure on electricity is also positively associated with both income and ethnicity. Controlling for additional covariates, the effects hold but decrease in magnitude. Fig. 3 shows different expenditure patterns comparing majority and minority ethnic groups in Vietnam. With

Table 3
Features selected by LASSO technique.

rLASSO coefficients	Electricity consumption per capita (last month) Estimates	Electricity expenditure (last 12 months) Estimates
Intercept	−77.81	−2853.75
Income (log, per capita)	11.89	310.77
Household size	−2.20	101.17
Income: regular wage (1 member)	−2.6	na
Income: household production (1 member)	na	−100.67
Income: household production (2 members)	−2.82	−59.32
Income: own business (1 member)	na	87.36
Number of appliances	0.23	16.65
Fridge	9.43	452.12
Air Conditioner	20.30	1132.90
Washing machine	4.50	358.17
Computer	na	101.27
Electricity Price	−3.53	111.84
Poverty status	na	−15.98
Expenditure on kerosene	na	0.02
Size of the dwelling (squared meters)	na	1.07
Location in Midlands and Northern Mountainous Areas	na	−108.79
Residual standard error	19.57	547.5
Adjusted R-squared:	0.3042	0.524
Joint significance test	***	***

Note: 1, Statistical significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
na: not applicable because not selected by the LASSO approach.

increasing income, households of the majority group tend to raise their electricity expenditure more extensively than comparable households of the minority group. Consequently, electricity expenditure follows as similar trend as electricity consumption with substantial divergences between ethnic groups, channeled through income.

Based on the non-normal distribution of the dependent variable, the Sobel test once again yields insignificant results with a p-value of 7.59. Nevertheless, non-parametric bootstrapping establishes a partial mediation effect of income on electricity expenditure. A significant total effect confirms a relationship between ethnicity and electricity expenditure. Accordingly, a significant indirect effect further underlines the mediating role of income. A significant direct effect indicates that although income acts as a mediator, a direct relationship between ethnicity and electricity expenditure can still be established. As a result, in the case of electricity expenditure, income acts as a partial mediator.

4.4. Regression results

This section reports the results of estimating model *(1),* which includes an interaction term between ethnicity and income to reflect the indirect effect of ethnicity on electricity through income, and confirms findings from section 4.3. This section proposes three sets of regressions with increasing numbers of control variables. In the first set of regressions, which takes ethnicity as the only regressor of electricity consumption and expenditure, the coefficients on Kinh (value of 1 for belonging to the majority group, 0 to one of the ethnic minorities) are positive, indicating that belonging to the majority group increases electricity use (Table 5, panels A and B). The obtained results confirm previous findings for other countries, such as for example Uganda, where ethnic affiliation is strongly linked with access to electricity (World Bank, 2013). Besides, the results corroborate that the persistent economic and socio-economic breach between members of Kinh and non-Kinh households, highlighted by Singhal and Beck (2015), did not diminish over time but rather remains present. Remarkable difference in standards of living between minority and majority ethnic groups, described by Baulch et al. (2008), continue to persist, reflecting in differential electricity use and expenditure.

Next, the dual role of income (direct and indirect) is added to the regression sets 2 and 3, which exclude and include additional controls respectively. The interaction term is significant, confirming that the effect of income on electricity differs whether the household belongs to the majority or to the minority ethnic group (see also Singhal and Beck, 2015). The effect of income on electricity for non-Kinh is captured with the positive coefficient on income (14.4 without controls and 8.3 with controls), while the effect of income for Kinh is obtained by taking the coefficient on income plus the interaction term. Given that the coefficient on the interaction term is positive (7 without controls and 4.9 with controls), the effect of income is larger for Kinh than for non-Kinh households. An extra unit of income leads to a larger increase of electricity consumption for members of the majority group than for members of the ethnic groups. The findings give substance to Baulch et al. (2012), who indicate that socio-economic endowments as well as returns to endowments did improve faster for Kinh households over the period between 1993 until 2004. Similar observations are made for electricity expenditure, which confirm that ethnicity plays a role on electricity usage both directly and indirectly via a differentiated income effect. The coefficients on all other control variables adopt the expected signs.[2] Our results are in line with previous findings, where members of the majority group show improved outcomes with respect to the overall standard of living, life expectancy, health and nutrition (Pham Thai et al., 2010; Mbuya et al., 2019) as well as to access to credits or purchasing power (Nguyen et al., 2020) compared to non-Kinh households. As a result, Kinh members benefit to a larger degree from available resources, which also reflects in electricity usage. Summarized by Singhal and Beck (2015), indications for welfare convergence in Vietnam are thus not present between different ethnic groups.

5. Discussion of results

5.1. Lifestyle and basic needs for electricity

This section aims to clarify the lower increase of electricity consumption by non-Kinh groups than by Kinh when income rises, and identify potential obstacles that limit upward consumption.

It is sometimes argued that members of ethnic groups adopt lifestyles that are less energy-intensive compared to groups dominated by urban culture, suggesting that smaller amounts of modern electricity are sufficient to ensure satisfaction of ethnic groups' basic needs. This could constitute a reason ethnic minorities do not increase their electricity consumption as much as their counterparts from majority groups do when income rises. To verify this, we can exploit the information collected in the survey as to whether households subjectively feel they face shortage of electricity to satisfy their basic needs. 'Basic needs' are not defined in the questionnaire, and neither are the related quantities of electricity necessary to meet those needs. Households rather report their own appreciation, in relation to their actual electricity consumption, reflecting their vision of lifestyle and basic needs. About the same proportion of Kinh (24.9%) and non-Kinh (25.9%) report that their

[2] Under this configuration, the negative coefficient on Kinh represents the effect of being Kinh when income is 0, which is not very interpretable as no household has zero income. More generally, the effect of being Kinh is obtained by adding the coefficients on *Kinh* and on *Kinh*Income* at various levels of income. In other words, the effect of being Kinh is: $-62.70 + 6.99 * Income$ (for Set 2, consumption). With this, the effect of being Kinh becomes positive for any income level above 8.9, which is extremely low. This reinforces the finding that belonging to the ethnic majority has an overall positive effect on electricity consumption. The same goes for electricity spending, for which the effect of being Kinh is positive for any household with total income level above 8.7 (virtually all households).

Table 4
Mediation test for income and electricity.

PANEL A: Electricity Consumption

Coefficient	Condition 1 Estimates	Condition 2 Estimates	Condition 3 Estimates	Condition 1 inc. control Estimates	Condition 2 inc. control Estimates	Condition 3 inc. control Estimates
Intercept	8.87 ***	12.74 ***	−164.35 ***	9.14 ***	31.45 ***	−80.63 ***
	(0.02)	(0.66)	(4.33)	(0.02)	(1.04)	(5.39)
Ethnicity Dummy	0.60 ***	12.05 ***	0.13	0.30 ***	3.20 ***	−0.46
	(0.02)	(0.73)	(0.71)	(0.01)	(0.68)	(0.68)
Income (log, per capita)			19.97 ***			12.26 ***
			(0.48)			(0.58)
Control	No	No	No	Yes	Yes	Yes
Observations	6373	6373	6373	6373	6373	6373
R^2 adjusted	0.165	0.041	0.243	0.486	0.286	0.332

PANEL B: Electricity Expenditure

Coefficient	Condition 1 Estimates	Condition 2 Estimates	Condition 3 Estimates	Condition 1 inc. control Estimates	Condition 2 inc. control Estimates	Condition 3 inc. control Estimates
Intercept	8.87 ***	441.34 ***	−5432.21 ***	9.26 ***	−32.82	−2809.35 ***
	(0.02)	(22.32)	(147.33)	(0.02)	(34.87)	(176.54)
Ethnicity Dummy	0.60 ***	466.88 ***	71.42 **	0.19 ***	127.44 ***	70.49 **
	(0.02)	(24.77)	(24.21)	(0.01)	(22.32)	(22.17)
Income (log, per capita)			662.46 ***			299.81 ***
			(16.46)			(18.70)
Controls	No	No	No	Yes	Yes	Yes
Observations	6373	6373	6373	6373	6373	6373
R^2 adjusted	0.165	0.053	0.245	0.600	0.516	0.535

Notes: 1, Statistical significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
2, Standard errors in the brackets.

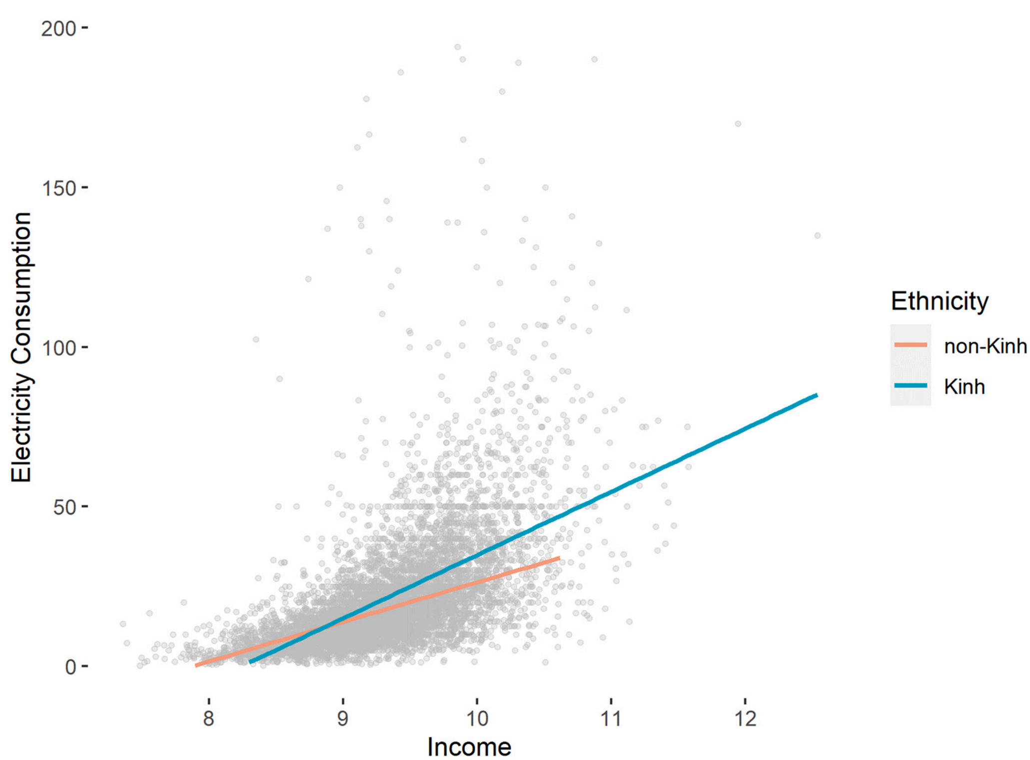

Fig. 2. Income and electricity consumption, by ethnicity.

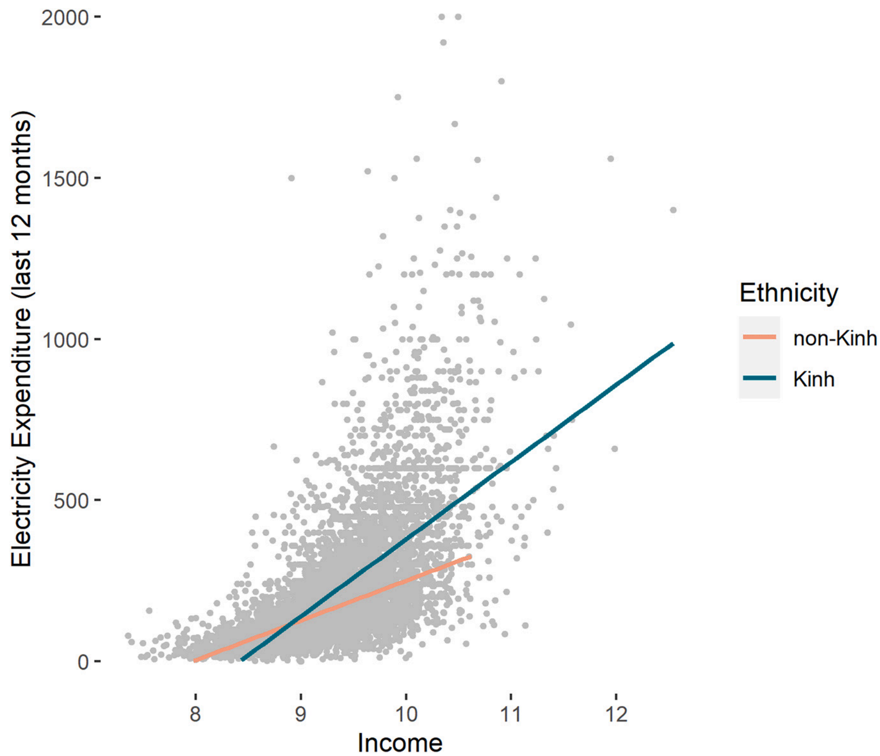

Fig. 3. Income and electricity expenditure, by ethnicity.

electricity consumption is insufficient. Fig. 4 further shows that among households who report sufficient electricity consumption (electricity shortage = 0), consumption levels are lower for non-Kinh than for Kinh households. This suggests that most non-Kinh are able to fill their basic needs with lower amounts of electricity than Kinh, indicating different perception of basic needs between ethnic groups. A similar pattern is observed among households who report experiencing electricity shortage (electricity shortage =1), where Kinh consider electricity insufficient at higher levels of electricity consumption than non-Kinh. The perception of shortage is thus linked to ethnic affiliation, which indicates diverging perception of basic electricity needs. This, in turn, is a possible reason for a decelerated uptake in electricity usage rates for non-Kinh households, for given income levels.

5.2. Appliances

Electricity cannot be used without appliances to transform it into useful services. Therefore, electrical equipment of a household, such as light bulbs, electric fans, televisions, fridges or washing machines, is a key factor that determines the ability of households to increase their electricity consumption and define electricity consumption patterns. Access to markets to purchase appliances is thus critical for households who want to access the services offered by modern electricity (watching television, storing food in a fridge…) and is hence more challenging for households living in rural and remote communities. This section shortly examines the appliance stock of Kinh and non-Kinh. Non-Kin households possess on average smaller number of appliances (3.1) than Kinh households (4.9). As seen in Fig. 5, this pattern is visible at all levels of electricity consumption, expect for very high levels. Therefore, even when Kinh and non-Kinh households have the ability to consume similar levels of electricity, non-Kinh houses are less well-equipped than houses of the Kinh majority. At this stage the interpretation requires caution. Similar electricity consumption with fewer appliances could indicate a more intensive use of each appliance, or that appliances are less energy-efficient. A more difficult access to markets to purchase appliances, a lower desire to purchase multiple electric appliances and pursue a modern, energy-intensive lifestyle, or other priorities could all be reasons for members of ethnic communities to own fewer appliances than their Kinh counterparts. The comparatively limited appliance stock of non-Kinh households limits their possibility to increase electricity consumption when income increase and thus could be one underlying reason for the main results of this study.

5.3. Effect at various income levels

To explore the possibility that the ethnicity effect detected in the results presents some heterogeneity, the analysis is further repeated at various quantiles of income distribution. In relation to results of Son and Yoon (2020), who find that energy utilization is not proportional to income level and low-income households have lower electricity uptake rates than other households, we aim to verify the possibility that the indirect effect of race through income could also vary with the income level. The sample of rural households is split into 5 groups according to their income. For each group, the LASSO approach selects the relevant set of predictors, which turn out to differ across various groups. Table 6 reflects the inclusion of these variables in the regression analysis, where *na* indicates that a predictor is selected for certain income groups but not for others. For example, to be located in the remote northern region is a major determinant of electricity usage for the two lowest income groups, but not for the others. Electricity prices is a major determinant for the 3 lowest income groups only. On the other hand, in the 2 higher income groups, electricity usage is more determined by earning income through wage. In addition, the presence of large appliances (air condition, washing machine) is an important determinant for the highest income group.

The coefficients reported in Table 6 for the regression set 3 (with LASSO-selected controls), for electricity consumption, are of similar sign as previously. Interestingly, the coefficients on income, ethnicity and the interaction term are only significant for the lowest-income group and the highest-income group. This indicates that the indirect effect of ethnicity on electricity usage is only valid for those groups, but disappears for middle-income households. Specifically, Fig. 6 shows the total

Table 5
Indirect income effects of ethnicity on electricity consumption and expenditure.

	Electricity consumption per capita (last month)			Electricity expenditure (last 12 months)		
	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3
	(Ethnicity only)	(Ethnicity and income)	(All controls)	(Ethnicity only)	(Ethnicity and income)	(All controls)
Coefficient	*Estimates*	*Estimates*	*Estimates*	*Estimates*	*Estimates*	*Estimates*
Intercept	12.74 *** (0.66)	−114.74 *** (9.59)	−45.80 *** (9.77)	441.34 *** (22.32)	−2829.75 *** (325.12)	−2184.53 *** (297.46)
Kinh	12.05 *** (0.73)	−62.70 *** (10.87)	−44.88 *** (10.42)	466.88 *** (24.77)	−3224.83 *** (368.45)	−707.92 * (299.15)
Income (log, per capita)		14.38 *** (1.08)	8.35 *** (1.08)		368.94 *** (36.6)	229.97 *** (32.65)
Kinh* Income (log, per capita)		6.99 *** (1.21)	4.94 *** (1.16)		366.84 *** (40.92)	86.46 ** (33.14)
Household size			−2.26 *** (0.18)			94.82 *** (5.46)
Income source: regular wage (1 pers.)			−3.06 *** (0.5)			na
Income source: household production (1 pers.)			na			−89.67 *** (22.28)
Income source: household production (2 pers.)			−2.35 *** (0.54)			−33.87 (19)
Income source: business (1 pers.)			na			82.20 *** (15.53)
Number of appliances			0.2 (0.13)			17.10 *** (3.7)
Fridge			9.40 *** (0.67)			454.65 *** (19.15)
Air conditioning			22.30 *** (2.1)			1106.30 *** (60.04)
Washing machine			5.25 *** (1.12)			376.36 *** (32.24)
Computer			na			113.65 *** (28.47)
Electricity prices			−3.53 *** (0.3)			109.90 *** (8.6)
Poverty status			na			−17.33 (22.64)
Kerosene expenditure			na			0.02 *** (0)
Size of dwelling, in sq. meters			na			1.06 *** (0.21)
Northern			na			−90.97 *** (20.98)
Observations	6373	6373	6373	6373	6373	6373
R^2 adjusted	0.041	0.247	0.334	0.053	0.254	0.535

Note: 1, Statistical significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
2, Standard errors in the brackets.
na: not applicable because not selected by the LASSO approach.

effect of income on electricity consumption for Kinh and non-Kinh separately, by adding the coefficients on income and on the interaction term for Kinh, and using solely the coefficient on income for non-Kinh. The results clearly show a smaller effect of income on electricity usage for non-Kinh at low-income levels. This is somewhat reversed at high income levels, where non-Kinh households do increase electricity usage faster than Kinh with a given increase in income, likely ‘catching up’ on their electricity consumption compare to Kinh households. Therefore, these results indicate that members of ethnic minorities in Vietnam do operate an energy transition, but that they require much higher levels of income than their counterparts of the ethnic majority to do so. This also indicates that at middle-income levels, ethnicity does not play a significant role on rural electricity consumption in Vietnam. It is mostly within the very low-income strata that ethnicity acts as a barrier to increasing electricity consumption in the rural sector.

5.4. Robustness checks

5.4.1. Urban households

Among the non-Kinh households of the survey, 12% lived in urban area. The same analysis is performed for the 2620 urban households of the initial survey to see if similar patterns of income effects are observed for them. First, the LASSO analysis reveals that the variables identified as main features of the regression are close to those for the rural sample, shown in Table 7.

The models are significant and retain sufficiently explanatory power (adjusted R-squared at 0.42 and 0.51 for consumption and expenditure respectively, as well as joint significance of the coefficients). For urban households, being located in the central region is significantly, but negatively, associated with electricity usage. Poverty status, expenditure on kerosene, and size of the dwelling are not predictors strong enough to be kept. Among income sources, only those that relate to households' own production are selected, while obtaining a regular salary from wage or running an own business is not deemed sufficiently associated with electricity usage. The same appliance variables are selected as for the rural households, at the exception of having a computer.

Second, the mediation analysis generates different results than for rural households, both in terms of magnitude and significance. With increasing income, electricity consumption increases by 37.55 kWh for urban households when ethnicity only is included as control. Taking into

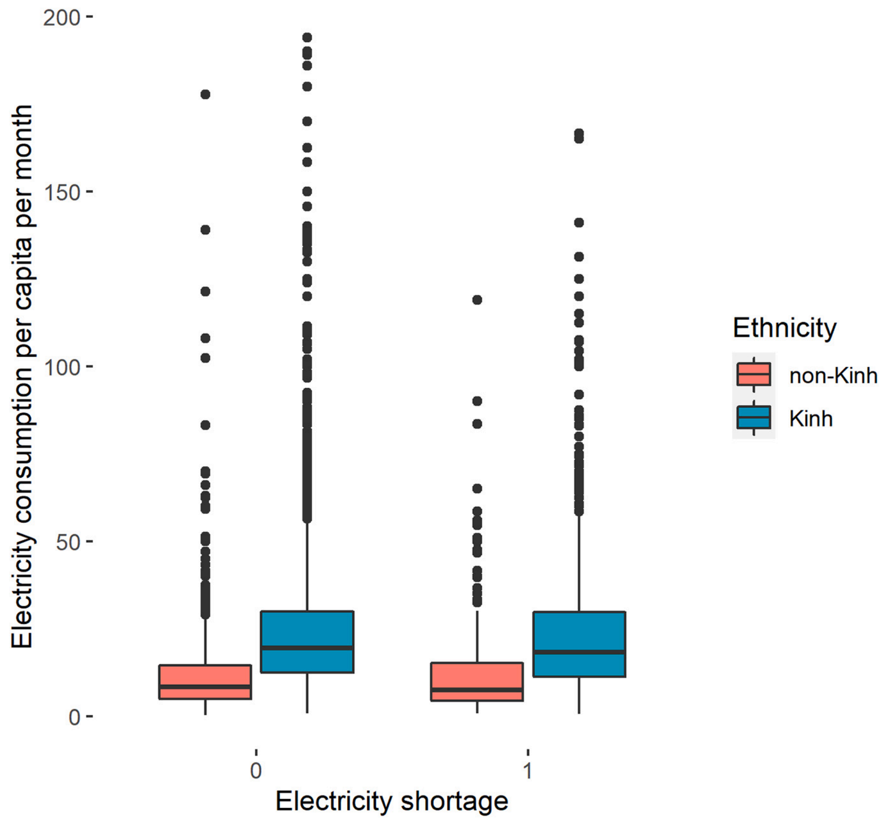

Fig. 4. Levels of electricity consumption and electricity sufficiency/shortage, by ethnicity.

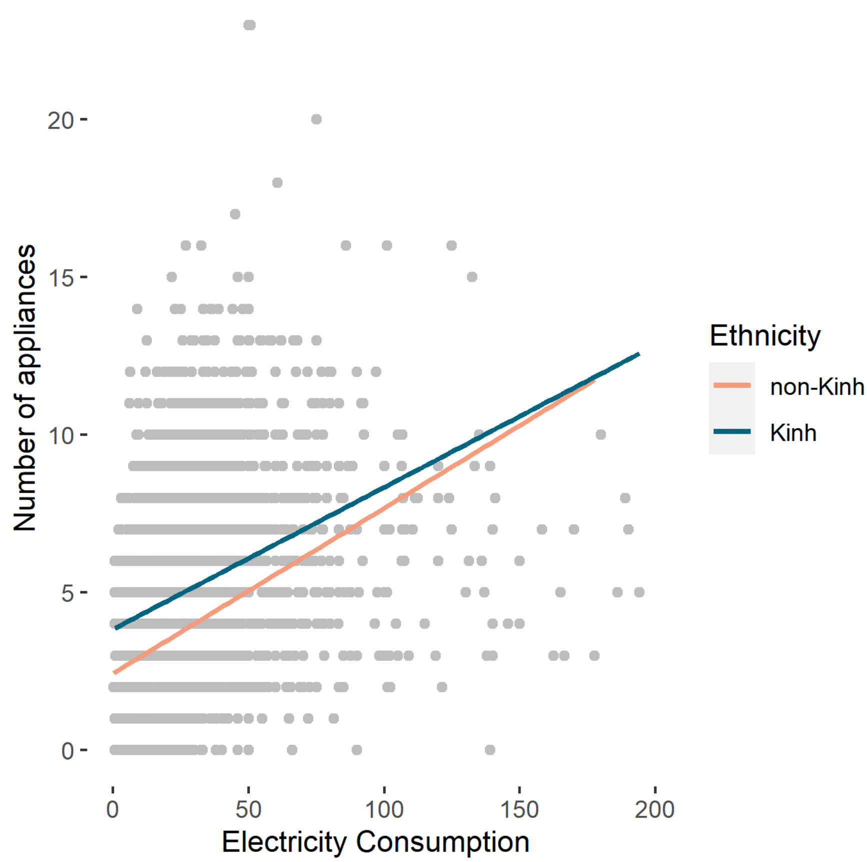

Fig. 5. Appliance ownership and electricity consumption, by ethnicity.

consideration additional control variables, the effect holds but decreases in size (23.75 kWh). Majority ethnicity appears to have a significant, positive impact on electricity consumption. Yet, the effect disappears when the control variables are included. Thus, in an urban context, ethnic belonging does not seem to impact upon electricity consumption. Consequently, proposed conditions by Baron and Kenny (1986) only hold when we consider electricity consumption without additional control variables.

As previously, the Sobel test renders insignificant results (*p*-value of 1.40), which can be attributed to the non-normal distribution of our sample. Although the bootstrapping approach indicates full mediation of income on electricity consumption, the results become insignificant when selected control variables are included.

With regards to electricity expenditure, a similar trend is observed where ethnicity is not a significant determinant for electricity expenditure in an urban context. The conditions stated by Baron and Kenny (1986) do not hold, which is further confirmed by an insignificant Sobel test (p-value of 8.8) and by the bootstrapping approach, confirming the insignificant indirect effect of income both on electricity expenditure and consumption based on ethnicity.

Finally, the regression models with interaction between ethnicity and income confirm the absence of a significant direct and indirect role of ethnicity on electricity consumption and expenditure.

Table 6
Regression with interaction term and LASSO-selected controls, by income quantile.

	Electricity consumption per capita (last month)				
	Quantile 1	Quantile 2	Quantile 3	Quantile 4	Quantile 5
Max. monthly income per capita	5358	8610	11,504	15,447	27,529
Coefficient	*Estimates*	*Estimates*	*Estimates*	*Estimates*	*Estimates*
(Intercept)	−12.77 (8.91)	−144.15 (118.42)	−32.74 (135.14)	−185.17 (189.39)	−605.56 ** (191.14)
Kinh	−34.39 * (15.73)	−62.30 (131.48)	−97.31 (142.83)	36.79 (197.43)	420.87 * (192.31)
Income (log, per capita)	3.21 ** (1.04)	17.66 (13.09)	6.13 (14.44)	22.77 (19.62)	65.84 *** (19.06)
Kinh* Income (log, per capita)	4.08 * (1.83)	7.25 (14.53)	10.63 (15.27)	−3.74 (20.46)	−42.37 * (19.18)
Household size	−0.95 *** (0.12)	na	−1.51 *** (0.27)	−2.74 *** (0.43)	−6.30 *** (0.63)
Fridge	5.87 *** (1.13)	8.26 *** (1.51)	9.28 *** (0.89)	12.24 *** (1.18)	13.20 *** (1.83)
Cooking with electricity	1.58 ** (0.49)	na	na	na	na
Electricity prices	−1.57 *** (0.23)	−3.51 *** (0.61)	−3.33 *** (0.50)	na	na
Northern	−1.74 *** (0.51)	−1.88 (1.52)	na	na	na
Wage (1 pers.)	na	na	na	−5.40 *** (1.16)	−6.34 *** (1.64)
Air conditioning	na	na	na	na	23.56 *** (3.62)
Washing machine	na	na	na	na	6.88 ** (2.17)
Observations	1275	1274	1275	1274	1275
R^2 / R^2 adjusted	0.181 / 0.176	0.072 / 0.068	0.129 / 0.125	0.134 / 0.130	0.261 / 0.257

Note: 1, Statistical significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
2, Standard errors in the brackets.
na: not applicable because not selected by the LASSO approach.

The resulting coefficients, shown in Table 8, are mostly of the expected signs, at the exception of a negative association between the possession of a computer and electricity consumption. The estimates on ethnic minority and the interaction term become insignificant for the urban sample when income, alone or with the other control variables, is included (sets 2 and 3). The income effect of ethnicity on electricity usage thus disappears for urban dwellers. For them, it appears that an increase in income has the same effect on electricity usage, whether the household belongs to the majority group or to an ethnic minority. Therefore, we can deduct that for members of minorities who live in urban centers, the opportunities to increase electricity usage offered by a higher income are the same as for members of the majority group.

5.4.2. *Racial distinction*

Given the great plurality of ethnic groups in Vietnam, other definitions of majority and minority ethnic groups can be adopted to distinguish how the racial profile affects electricity use. Ethnic belonging can be grouped under larger categories. The Kinh together with the Muong, Tho, Chut form the major Vietic ethnic group, which represents 83.7% of the total sample. Thus, while all Kinh are Vietic, most but not all Vietic are Kinh. The above analysis was conducted using the Vietic/Other distinction as racial divide, instead of Kinh/non-Kinh, but produces similar results that are not reported here.

6. Conclusion

It is central to human development and environmental sustainability that poor and rural households increase their electricity usage, as replacement of polluting, unsafe and inefficient kerosene, coal or biomass fuel sources. The Vietnamese economy experienced dynamic growth, accompanied by a reduction in poverty rates and considerable improvement in living standards. Particular effort has been made to expand infrastructure, which resulted in almost universal access to the electric grid for rural households. Nevertheless, even connected to grid electricity, members of ethnic minorities continue to consume prominently lower amounts of electricity compared to members of the Kinh majority. Race and ethnicity have known effects of discrimination and marginalization on access to economic opportunities, human development and living standards. On that account, the present study, in line with previous research, helps clarify the link between ethnicity and electricity use.

In particular, the research questioned the role of ethnic belonging in relation to the most important factor that drives household transition to electricity: rising income. It is well established that members of socially disadvantaged groups often experience lower income levels, but the present analysis further investigated how rising income affects electricity use of members of the majority and the minority groups differently. This study proposes a robust methodological framework where feature selection is operated with the least absolute shrinkage and selection operator (LASSO) and where a formal analysis of mediation is conducted to establish whether income acts as a mediation factor for ethnicity on electricity.

Based on data for rural households from the Vietnam's 2010 Household Living Standards Survey, the results highlight the positive impact of being a member of the majority group on electricity consumption. According to the non-parametric bootstrap approach, complementing the methodology suggested by Baron and Kenny (1986), we find significant evidence that income fully explains the effect of ethnicity on electricity consumption, while it only acts as partial mediation effect in the context of electricity expenditures. The empirical approach then confirms a different relationship between income and electricity for Kinh and non-Kinh households. An extra unit of income results in a larger increase of electricity consumption for members of the majority group than for non-Kinh households. Although income remains the most important factor for households to increase electricity usage, higher income levels do not translate into the same opportunities for

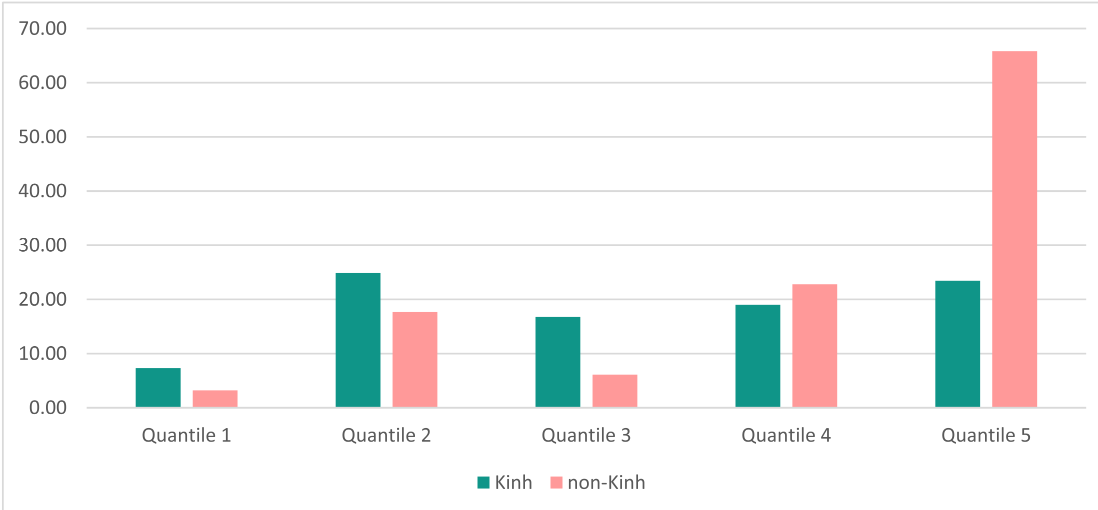

Fig. 6. Total effect of income on electricity consumption, at various income levels.

Table 7
Features selected by LASSO technique for urban households.

rLASSO coefficients	Electricity consumption per capita (last month) Estimates	Electricity expenditure (last 12 months) Estimates
(Intercept)	−151.17	−10,545.1
Income (log, per capita)	21.02	1026.72
Household size	−4.77	350.73
Income source: household production (1 member)	−1.91	−162.32
Income source: household production (2 members)	0.02	na
Number of appliances	0.86	64.72
Fridge	4.70	−17.36
Air Conditioner	26.42	1528.79
Washing machine	2.81	166.8
Computer	na	284.6
Electricity Price	−6.02	369.94
Location in Midlands and Northern Mountainous Areas	na	−356.03
Location in Central Region	−5.71	−484.55
Residual standard error	30.17	1511
Adjusted R-squared:	0.4186	0.5101
Joint significance test	***	***

Note: 1, Statistical significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
na: not applicable because not selected by the LASSO approach.

Kinh and non-Kinh households to increase electricity consumption. Linking the results to the theoretical framework of Gertler et al. (2016), we conclude that although many Vietnamese households transitioned to higher income levels and passed a critical threshold for the purchase of energy-using consumer goods, the consumption of electricity remains low for members of the ethnic minority. However, the indirect effect of ethnicity on electricity is no longer statistically significant for rural households of middle-income levels, while it is reversed for households of the top income quantile, indicating that, with an extra unit of income, wealthy members of the minority increase their electricity consumption more than wealthy members of the majority group. Similarly, the application of our approach to urban households in Vietnam (where 12% of the non-Kinh live) yields different results, indicating that members of ethnic groups located in urban areas are no longer exposed to ethnic adversity with regards to electricity consumption. In summary, this suggests that it is mostly poor households of the rural sector that experience a different speed of transition to electricity when their income rises. The ethnic disparity appears to delay the transition to electricity consumption until minority households can reach higher levels of income or move to urban areas.

Consequently, the present study suggests that policies attempting to resolve ethnical differences in electricity consumption should look beyond infrastructure and grid connection, but rather identify additional barriers that rural ethnic minorities face with respect to energy use. The smaller translation of income into electricity usage for minorities groups points to non-income barriers. Non-Kinh households appear to diversify increasing income into other goods and services than electricity. Consequently, inquiries emerge about why and how those households choose to spend or save extra income, demanding for supplemental research. In addition, there are ethnic disparities in perception of basic needs for electricity and patterns of appliance ownership, but the reasons for it - conscious cultural or lifestyle choice, priority of other needs, or other obstacles such as access to market or sufficiency of power supply - remain unclear. This requires further investigation of the link between ethnicity, living standards and economic growth. Besides, Kinh and non-Kinh households might not only diverge in electricity consumption but also in the consumption of other services. New insight can also be gained through the economic assessment of opportunity costs between traditional energy sources in remote areas and modern electricity. Therefore, specific recommendations based on obtained research results entail the supplemental collection of quantitative and qualitative data in rural and ethnic households of the country. Where possible, data collection should include geo-location of households or their village to better assess the effect of remoteness.

Of particular importance we consider the implementation of tailor-made policy programs, which so far have not met minorities' energy needs to a satisfying degree. Based on the results obtained, we suggest a holistic approach of governmental programs particularly for non-Kinh households. It is immanent that those programs take into consideration non-income related barriers to electricity use and the reasons households still rely on traditional fuels. Furthermore, within a holistic approach, considerations previously raised by other scholars, such as the lack of familiarity with electricity (Ranganathan, 1993; Bernard, 2012), the potential impact of neighbor's behavior (Bernard and Torero, 2015) as well as a possible gap of knowledge about the benefits of modern electricity use should all be taken into consideration when designing

Table 8
Indirect income effect on electricity consumption, urban households.

	Electricity consumption per capita (last month)			Electricity expenditure (last 12 months)		
	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3
	(Ethnicity only)	(Ethnicity and income)	(All controls)	(Ethnicity only)	(Ethnicity and income)	(All controls)
Coefficient	*Estimates*	*Estimates*	*Estimates*	*Estimates*	*Estimates*	*Estimates*
Intercept	34.12 *** (2.95)	−286.37 *** (34.03)	−170.39 *** (33.46)	1473.08*** (211.92)	−12,331.52 *** (2776.43)	−12,986.9 *** (2633.5)
Kinh	12.92 *** (3.06)	−43.26 (35.62)	−9.34 (34)	748.02 *** (220.1)	−3742.8 (2905.56)	1545 (2666.41)
Income (log, per capita)		33.75 *** (3.58)	23.40 *** (3.49)		1453.67 *** (291.65)	1287.28 *** (273.85)
Kinh* Income (log, per capita)		4.13 (3.73)	0.38 (3.55)		386.19 (304.05)	−196.31 (278.49)
Household size			−4.04 *** (0.47)			423.49 *** (37.21)
Income source: household production (1 prs.)			−1.52 (2.01)			−226.27 (121.62)
Income source: household production (2 prs.)			−1.11 (2.46)			na
Number of appliances			0.60 * (0.25)			67.78 *** (20.03)
Fridge			7.04 *** (1.53)			80.89 (120.93)
Air conditioning			26.59 *** (2)			1719.43 *** (157.8)
Washing machine			2.05 (1.6)			109.66 (126.65)
Electricity prices			−6.84 *** (0.88)			340.54 *** (69.7)
Central			−5.39 * (2.35)			−457.78 * (186.4)
Northern			na			−454.52 ** (156.14)
Computer			na			217.64 (124.11)
Observations	2620	2620	2620	2620	2620	2620
R^2 adjusted	0.006	0.349	0.432	0.004	0.159	0.316

Note: 1, Statistical significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
2, Standard errors in the brackets.
na: not applicable because not selected by the LASSO approach.

future governmental programs.

CRediT authorship contribution statement

Lucie Maruejols: Methodology, Conceptualization, Software, Visualization, Writing - original draft. **Lisa Höschle:** Methodology, Visualization, Writing - review & editing. **Xiaohua Yu:** Conceptualization, Methodology, Supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2022.106222.

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