Energy transition, poverty and inequality: panel evidence from Vietnam

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Abstract

This paper investigates energy transition, energy poverty and energy inequality in Vietnam employing a longitudinal dataset of a nationally representative household survey. We use the data on residential energy expenditure of more than 9,000 households over the period 2004 - 2016. We find a transition from traditional energy to modern energy but this transition varies across regions, between ethnic and welfare groups and between rural and urban population. The poor and ethnic minority households still rely heavily on traditional energy sources such as coal and biomass to meet their energy demands. Electricity poverty has decreased but energy-cost poverty has increased. In addition, energy inequality tends to decrease at a more significant rate than income and consumption inequalities. We propose a national program for energy poverty alleviation be established to devise policies to lower households' energy costs. Further assistance to the poor and ethnic minority households is also recommended so that they can afford a higher level of electricity consumption.

Key words: household energy consumption expenditure; Gini coefficient; Lorenz curve; seemingly (un)related regression; probit regression.

1. Introduction

Energy is important to the economic growth and the everyday lives of people (Nussbaumer et al., 2012; Mainali et al., 2014; Halkos, 2017). The wealth status of a nation and its inhabitants is closely related to the type and extent of, as well as the access to, energy (Araújo et al., 2014). In fact, sustainable economic growth is associated with an increase in access to and use of clean energy. This is critical for sustainable development because clean energy use is more environmentally friendly, has fewer negative health impacts and does not contribute to climate change (Kaygusuz, 2012; Halkos et al., 2015). Thus, promoting the transition from traditional to clean energy would reduce the time and effort needed to achieve the United Nations (UN) Sustainable Development Goals (UN, 2018; Sugiawan and Managi, 2019).

However, sufficient and reasonable provision of clean energy remains a major challenge in many developing countries, where about 2 billion people still rely on traditional (biomass) fuels such as wood, agricultural residues and dung for their daily energy needs (van der Kroon et al., 2013) and about 1.4 billion people still suffer from a complete lack of access to electricity (Bridge et al., 2016). Adequate supply of clean energy in the developing world can also contribute to solving several development challenges such as food poverty and insecurity, inequalities in income, consumption, education and health care (Managi and Kumar, 2018). At the same time, socially discriminatory supply and distribution of energy can lead to severe social conflicts and instability (UN, 2018). In this regard, there are three important concerns with regard to energy use in developing countries that deserve further attention. The first relates to how energy use has been changed; the second to how energy has been distributed; and the third to how energy demand of the poor is met. These issues are commonly referred to as energy transition, energy inequality and energy poverty. Making energy transition more equitable and inclusive has been a norm in energy and development economics literature.

Even though energy transition, energy poverty and energy inequality are three different issues that need careful considerations, they are essentially interrelated, especially in developing countries. While energy transition reflects changes toward a (relatively) higher use of clean energy, energy poverty commonly refers to lack of access to clean energy and to dependence on the tradition of burning solid biomass to meet energy needs. Energy inequality indicates that access to (clean) energy is unfairly apportioned among different clusters of the population. As reported by the UN (2018), the interlinkages between energy transition, energy poverty and energy inequality from a developing country perspective are of particular concern, as it is often the poorest that end up paying a disproportionate share of income for energy. Therefore, enhancing the poor's access to clean energy sources is important due to its potential for increasing income for this group. In addition, access to energy will do nothing to alleviate poverty if it is not affordable for the lowest income households.

Vietnam is a typical case for an examination of energy transition, energy poverty and energy inequality. It is one of the fastest growing economies in the world with a very high rate of growth in foreign direct investment (Le and Tran-Nam, 2018). The annual gross domestic product (GDP) growth was at about 7% during the period 2004-2014 (Huy and Nguyen, 2019). However, rapid economic growth has resulted in an increasing share of the urban population and a growing disparity in living standards between rural and urban areas. Rural-urban migration is also high (Nguyen, *et al*., 2017). The country is home to 54 officially recognized ethnic groups, with about 85% of the population belonging to the majority ethnic group. Many ethnic minorities live in remote and mountainous areas and are largely excluded from public services. At the national level, income poverty has decreased from 58% in 1993 to 9.8% in 2016 with about 28 million people being estimated to have been lifted out of poverty over the period 1993-2013 (Benjamin et al., 2017; Do et al., 2019a), but heterogeneities in poverty are observed. At the regional level, the Northern region has highest share of the population subject to income poverty. This is also the case for ethnic minorities and for rural areas when compared to the ethnic majority group and urban areas, respectively. Obviously, Vietnam's economic achievements are simultaneously associated with various energy sector developments (Do and Sharma, 2011). For example, rural electrification efforts of the government led to 95% of rural households having access to electricity by 2008 (Khandker et al., 2013). However, the energy sector is still dominated by state-owned enterprises. In addition, even though the country has its own national income poverty alleviation strategy and is known for its progress in income poverty reduction, there have been no policies on energy poverty and energy inequality. To the best of our knowledge, there have also been no previous studies examining energy transition, energy poverty and energy inequality in this country.

Our study is designed to fill in this gap. We use a nationally representative household survey dataset, the Vietnam Household Living Standards Survey (VHLSS), to examine energy transition, energy poverty and energy equality in Vietnam. Our research questions include: (i) how have energy transition, energy poverty and energy inequality changed over time and how are they different between different population clusters? And (ii) what are the factors affecting energy consumption expenditure and energy poverty? We analyze these questions in both temporal and spatial contexts. Temporally, we construct a dataset covering the period from 2004 to 2016. Spatially, we disaggregate our analysis among agro-ecological regions, between rural and urban populations, between poor and non-poor households and between majority and minority ethnic groups. With regard to the first question, we expect that, in accordance with economic growth, energy transition has been clearly witnessed, energy poverty and energy inequality have been reduced, but there are differences in these regards at the sub-population levels. As a result, these differences affect energy consumption and energy poverty as referred to in the second research question. It means that the dependence on traditional (burning of biomass) fuels has decreased while the access to clean energy has increased. But these decreases and increases are different for different population clusters. Our findings thus provide policy decision makers with useful information for establishing public programs aimed at decreasing the dependence and use of traditional energy and improving the access to clean energy for individual households.

The remainder of the paper is structured as follows. Section 2 presents the theoretical basis for the study and reviews the related literature. Section 3 provides background information and describes the data and methods. Section 4 presents the results and discusses the findings. Section 5 concludes with policy implications.

2. Theoretical basis and literature review

2.1 Theoretical basis

Even though there is no universally accepted definition, energy transition is commonly understood as a change leading towards increased access to and use of clean energy, such as gas and electricity, and decreased dependence on traditional energy, such as coal and biomass fuels (Berkhout et al., 2012). Historically, the world has witnessed many changes in energy use. Some typical examples include the shifts from traditional energy sources such as biomass to fossil fuels such as coal and then from fossil fuels to cleaner energy sources such as electricity (Pachauri and Jiang, 2008; Fouquet, 2010).

In the literature, there are two main hypotheses relating to energy transition, namely the energy ladder and energy stacking. The energy ladder model is based on the consumer theory that when income increases or decreases, households consume not only more or less of the same goods, but they also shift to consuming higher or lower quality goods (Hosier and Dowd, 1987). Traditional fuels such as firewood and straw are considered inferior goods for comparatively high-income households but normal goods for low-income households. The energy ladder model assumes that households have an ordered preference for different energy sources with regard to cleanliness, convenience, versatility and efficiency. Therefore, households will move from traditional energy such as biomass to modern energy such as electricity when their income changes. This model has two major limitations. First, energy transition is described as unidirectional and linear. In other words, energy transition is the complete replacement of one energy by another. Second, its assumption that only one specific energy is used for a particular use ignores the fact that multiple energies are employed for a given use (Figure 1).

(Figure 1 here)

Figure 1: Energy ladder and energy stacking models (sources: Hosier and Dowd, 1987 and Han et al., 2018)

In responses to these limitations of the energy ladder model, the energy stacking model hypothesizes that households use a portfolio of energy sources even if they have different levels of income. The difference among energy portfolios is reflected in the variety of energy sources and their corresponding proportions to total energy. As a consequence, climbing the energy ladder does not mean abandoning any energy completely (Han et al., 2018), and energy transition does not necessarily imply a stepwise movement from one energy to another (Mensah and Adu, 2015). In this regard, energy transition is reflected by changes in the use of energy sources and their shares in total energy use and influenced by various factors representing socio-economic status.

2.2 Literature review

Energy transition is at the heart of energy policies in many countries (Ekholm et al., 2010; Grubler, 2012). In the developed world, energy transition has been intensively investigated, for example, by Kern and Smith (2008) for the Netherlands, by Strunz (2014), Frondel et al. (2015) and Hake et al. (2015) for Germany. While the focus has now shifted to renewable energy sources in developed countries (Gales et al., 2007; Solomon and Krishna, 2011; Pollitt, 2012; and Bridge et al., 2013), one main issue that remains in many developing countries is how to support people in getting better access to modern energy sources such as electricity (Khandker et al., 2013), especially in rural areas (Mainali et al., 2014; Baiyegunhi and Hassan, 2014). Support is needed as a high proportion of the population in developing countries still rely on traditional energy sources. However, there are considerably fewer studies on energy transition in developing countries, with a few exceptions such as Campbell et al. (2003) for Zimbabwe, Yuan and Zuo (2011) and Zheng et al., (2014) for China, Wickramasinghe (2011) for Sri Lanka, and Sokona et al. (2012) for Africa. Previous studies, however, place a greater emphasis on factors affecting energy choice (e.g. between traditional and modern energy) and on the welfare impact of access to modern energy (Rahut et al., 2014; Alem et al., 2016) without sufficient consideration that households' use of alternative energy sources is interrelated.

With regard to energy poverty, while it is commonly understood as a certain level of energy consumption that is insufficient to meet the basic energy needs of individuals and households, there is no widely accepted consensus on approaches and indicators for measuring energy poverty. This leads to the situation that different studies provide different estimates of energy poverty (Rademaekers et al., 2016). In general, there are three major approaches to measuring energy poverty. The expenditure-based approach compares the energy costs of households with some absolute or relative thresholds in order to provide a proxy for the extent of energy deprivation (Khandker et al., 2012). The consensual approach is based on self-reported assessments of housing conditions and the ability to attain basic necessities. The direct measurement approach examines if the energy services achieved in the home are sufficient to meet a set standard. The expenditure-based approach is the most popularly used due to its objectivity and the quantifiable nature, which are the main disadvantages of the consensual approach. The direct measurement approach is the least popular, especially in developing countries as it requires the data of both energy services (e.g. heating) and the respective environmental conditions (e.g. housing conditions). Another approach that is more relevant and has also been popularly used in developing countries is based on the level of access to modern energy sources. This approach indicates that heavy reliance on solid fuels for cooking and heating is an indication of energy poverty. According to González-Eguino (2015), indoor pollution causes 1.3 million deaths per annum associated with the use of biomass in inadequate cookstoves in developing countries. Thus, a higher dependence on traditional energy indicates a higher level of energy poverty and better access to clean energy can reflect a lower level of energy poverty. In these regards, it is better to use more than one approach to measuring energy poverty.

Energy poverty is closely associated with income or consumption poverty. At the global level, even though wealthier countries tend to have a lower level of energy poverty and poor countries depend much more on traditional energy sources, energy poverty still exists in developed countries - see for example, in Italia (Fabbri, 2015), in the United Kingdom (Liddell et al., 2012), in Japan (Okushima, 2016), and in the European Union (Bouzarovsk et al., 2012). Obviously, energy poverty is more severe in developing countries. Khandker et al. (2012) show that energy poverty in rural and urban India is about 57% and 28% while income poverty is at the respective levels of 22% and 20%. They conclude that income growth is needed to reduce energy poverty. Barnes et al. (2011) report that 58% of rural households in Bangladesh are energy poor compared to 45% that are income poor. Given the close association between income poverty and energy poverty, current literature tends to focus mainly on the factors affecting the former and less on the latter. In the same vein, while income and consumption inequalities have been intensively examined, fewer studies have focused on energy inequalities (Joyeux and Ripple, 2007; Soile and Mu, 2015; Wu et al., 2017). Increasing energy inequality may lead to further disempowerment of those who are already at a disadvantage and to, perhaps, great social unrest in the future.

In summary, the literature review indicates several points that deserve further attention. First, energy transition, energy poverty and inequality have usually been examined separately. While rapid economic growth might facilitate energy transition and reduce energy poverty, this might lead to a growing imbalance in access to energy. Such a separate consideration provides an incomplete picture of energy use. Second, previous studies focus on a single type of energy such as electricity, whereas it is well-known that households in developing countries typically consume a mixture of different energy types. Hence, there is a need to examine the factors affecting the consumption of different energy types in a simultaneous and related manner. Third, previous studies often lack long-term and disaggregated data. Thus, they provide only a snapshot of the situation of energy use at a point in time. Our study therefore contributes to current literature in several ways. We examine these three important issues relating to energy consumption together in a rapidly growing economy, Vietnam. We use a long-term dataset that is nationally representative and then disaggregate our analysis at different sub-population levels. We apply an econometric framework that takes into account the interrelationship between different energy types consumed by individual households in examining the factors affecting household energy expenditure and energy poverty. Thus, our findings are more robust and relevant, not only for Vietnam, but also for other rapidly growing economies.

3. Background information and methodology

3.1 Background information

Located in Southeast Asia, Vietnam is home to more than 95 million people of 54 officially recognized ethnic groups. 85% of the population belong to Kinh - the majority ethnic group, and the rest belong to the other 53 ethnic groups that are considered minorities who are mainly residing in mountainous and remote areas (Nguyen et al., 2013). The country spreads approximately 15 longitudes from north to south, and has a wide variety of biophysical and socioeconomic heterogeneities (WB, 2017). Thus, the country is divided into 6 regions, namely the Red River Delta (including the capital, Hanoi), the Northern, the Central Coast, the Central Highlands, the South East (including the biggest city, Ho Chi Minh city), and the Mekong River

Delta.[1] Table 1 presents some background information on these regions. Vietnam has experienced rapid economic growth during the last several decades. Per capita GDP measured in constant 2010 US$ increased from about 900 US$ in 1990 to about 6,700 US$ in 2017. Urbanization is also rapid, with an expectation that by 2020 about 45% of the population will live in urban areas (WB, 2016). These all have helped to reduce income poverty to a considerable extent. However, gains in income growth and poverty reduction are different between urban and rural areas as well as among regions and ethnic groups. At the same time, rising income inequality has been witnessed between ethnic groups and regions (WB, 2012).

Table 1: Background information on Vietnam's regions

(Table 1 here)

Vietnam has a large range of domestic primary energy sources such as coal, oil and gas in addition to biomass fuels. Due to rapid economic growth, the commercial primary energy supply grew by 9.5% per year during the 2001 - 2015 period, and electricity consumption grew by 11% per year during the 1999 - 2003 period. The country has made remarkable progress in expanding access to electricity, with the share of households without electricity decreasing from 50% in 1995 to 2% in 2014. However, the energy sector is mainly state-owned and managed by the Ministry of Industry and Trade, even though the government has been calling for private investment. This is partly due to the fact that Vietnam still lacks a market-based tariff mechanism. For example, the average electricity retail tariff was 1,622 VND/kWh as of March, 2015 which is only 73% of the long-run marginal cost (Asian Development Bank (ADB), 2015). The electricity supply is dominated by Vietnam Electricity (VNE), while that of gas and

[1] See Appendix 1 for the map of Vietnam and its agro-ecological regions.

petroleum products by PetroVietnam (PVN), and that of coals and coal products by Vinacomin. These all are state-owned enterprises.

3.2 Data

We use the Vietnam Household Living Standards Survey (VHLSS) which is a comprehensive nationwide survey implemented by the General Statistics Office of Vietnam (GSO) with the technical support from the World Bank and the United Nations Development Programme. The VHLSS is a well-designed survey by international standards and collected data are considered statistically representative at the national, rural, urban and regional levels.

The sampling procedure of the VHLSS involves three stages. In the first stage, a total of approximately 3,000 communes/wards were selected. Each of these communes/wards was then partitioned into a varying number of enumeration areas based on the 1999 or 2009 population censuses (the 2009 population census is used for the survey waves from 2012). In the second stage, three enumeration areas were randomly selected from each sampled commune/ward, making up the so-called master sample. The enumeration areas were changed in each wave. In the final stage, two separate samples of households from each sampled enumeration area are selected. The first sample of 15-20 households is used for the income survey (the so-called short household questionnaire). The second sample of 3-5 households is used for the income-consumption survey (the so-called long household questionnaire) (Huy and Nguyen, 2019). As we focus on households' energy expenditure, we use the long household survey data. Thus, the sample for our analysis includes about 9,000 households surveyed in 2004, 2006, 2008, 2010, 2012, 2014 and 2016 (about 65,000 observations). Due to the survey design, only a small proportion of the sample in a survey wave were re-interviewed in the following survey wave. Consequently, this does not allow us to establish a complete panel dataset.

The long household survey questionnaire records information on a household's demography, assets, housing and facilities, income and income generating activities and expenditure. The energy expenditure in the VHLSS questionnaire is recorded with respect to a list of various energy types (e.g. coal, coal briquettes, petroleum, kerosene, mazut oil, diesel oil, lubricant, liquefied petroleum gas (LPG), natural gas, fuelwood, husk, sawdust, straw, and sugar cane leaves). The respondent is asked on the expenditure for the purchase of each of these energy types and the monetary values of self-collection, from gifts or donations in the Vietnamese currency.

We disaggregate the entire sample into different sub-groups with respect to (i) income or consumption poverty status (two groups: poor and non-poor),[2] (ii) ethnicity (two groups: majority Kinh and minority), (iii) agro-ecological regions (six regions: Red River Delta, Northern, Central Coast, Central Highlands, South East, and Mekong River Delta), and (iv) urban or rural areas. This disaggregation allows us not only to examine but also to compare our issues of interest at these sub-population levels.

3.3. Measuring energy transition, poverty and inequality

As a household uses various types of energy at the same time, we classify all these energy types into four categories: (i) coal and biomass (including coal, coal briquette, firewood, husk, sawdust, and farm by-products such as straw, sugar can leaves, maize, jute, hemp, seagrass, stems), (ii) oil (petroleum, kerosene, mazut oil, diesel oil, lubricant), (iii) gas (liquefied petroleum gas (LPG), natural gas), and (iv) electricity. Coal and biomass are considered traditional energy sources in developing countries including Vietnam. They are

[2] A threshold value of US$2 daily per capita income or consumption was used to identify income or consumption poverty status.

more polluting and less efficient and convenient as compared to the latter three energy categories, of which electricity is the cleanest. As the energy stacking model indicates, energy transition can be reflected by changes in the use of energy sources and their shares in total energy use. Thus, examining changes in the use of these energy categories and changes in their shares of household energy expenditure over time allows us to track the transition from traditional to modern energy. Therefore, we use the following groups of energy indicators: (i) the share of users of each energy category (%), (ii) per capita expenditure of each energy category (US$), (iii) share of each energy category expenditure in household energy expenditure (%), and (iv) per capita energy expenditure (US$). Since electricity is homogenous in terms of quality, we use the national electricity prices to convert expenditure on it to a quantity. Thus, for electricity we have data on both quantity and expenditure. For other energy categories, we have only expenditure data. All monetary values are converted to 2005 US$ purchasing power parity (PPP).

For energy poverty, as indicated in the literature review section, it is better to use more than one approach to measuring energy poverty. We therefore use both the expenditure-based approach and the access to clean energy approach, with two indicators representing energy cost and electricity consumption. In respect to the energy cost indicator, a household is considered energy poor if (i) its share of per capita energy expenditure in disposable income is above the national median share, and (ii) the per capita household disposable income is smaller than 60% of the national median income. These two conditions indicate what is known in the literature as 'low income high energy cost' (LIHC) (see Hill, 2012). They reflect a situation where the household has low income but high energy costs and thus is categorized as being energy-cost poor. The advantages of using these relative instead of absolute threshold values with median income and median share in energy expenditure include (i) they allow recalculation each year and accountability for fluctuating conditions (e.g. prices), (ii) they take into account the income components, and (iii) due to the asymmetry of energy expenditure, the use of medians helps avoid the influence of extreme value in the distribution tail (Rademaekers et al., 2018). For electricity use, the literature usually uses a certain threshold of per capita electricity consumption (see for example Rademaekers et al., 2016). We use the lowest threshold proposed by the International Energy Agency of 100 kWh (Coelho and Goldemberg, 2013). This 100 kWh threshold of electricity use per capita per year is considered the minimum level to meet the basic need for electricity. Thus, a household is considered to be electricity poor if its per capita consumption of electricity is smaller than 100 kWh per year.

Regarding inequality, there are several approaches to measuring income or consumption inequality in general and energy consumption inequality in particular (see Jacobson et al., 2005). The Lorenz curve and the Gini coefficient are the most widely used (Wu et al., 2017). We follow Haughton and Khandker (2009) to construct the Lorenz curve while the Gini coefficient is calculated as follows:

$$G = 1 - \sum_{z=1}^{N} (X_z - X_{z-1})(Y_z + Y_{z-1}) \quad (1)$$

where G is the Gini coefficient for each year; X is the cumulative proportion of the population and Y is the cumulative proportion of energy expenditure. X is measured as the number of energy users in population group z divided by total population, with X_z indexed in non-decreasing order. Y is measured as the per capita energy expenditure used by population group z divided by energy expenditure of the total population, with Y_z ordered from the lowest to the highest. We construct the Lorenz curves and the Gini coefficients for all indicators of energy consumption as well as per capita household income and consumption.

3.4 Modelling factors affecting energy consumption and energy poverty

We apply several econometric regression models to examine the factors affecting energy consumption and energy poverty. Previous literature (e.g. Mensah and Adu, 2015; Kamiru et al., 2016; Bridge et al., 2016) show that the following variables might have significant effects on households' energy consumption and poverty: (i) household demographic factors such as age, education level and ethnicity of the household head and household size (Rahut et al., 2014), (ii) household livelihood strategies (e.g. wage employment or self-employment) (Alem et al., 2016) and (iii) the welfare status of the household (Gebreegziabher et al., 2012; Jingchao et al., 2019).

In this study, we use age, education level, ethnicity of the household head, household size and the share of dependent household members (less than 15 or more than 60 years old) to represent household's demographic characteristics. Whether the household participates in self-employment or forest extraction activities represents household livelihood strategies. For household wealth, instead of using household income to capture household wealth as in Jingchao et al. (2019), we use the real value of the household's durable assets given that the use of income creates econometric issues.[3] In addition, we also control for regional and temporal effects by using addition dummies for agro-ecological regions and for survey years (South East as the base region and 2004 as the base year).[4] To detect potential perfect multicollinearity, we apply the variance inflation test (VIF). The results of this test reject the null hypothesis.[5]

We use per capita energy expenditure (US$) to represent energy consumption since it indicates the actual expenditure of energy use of a household. We postulate the following ordinary least squares (OLS) model:

$$ln\_E_{it} = \alpha_0 + \alpha_1 H_{it} + \alpha_2 O_{it} + \alpha_3 A_{it} + \varepsilon_{it} \qquad (2)$$

3 First, household income is normally considered a "short-term" welfare indicator as it is volatile overtime, especially for non-wage employment household members in developing countries. Second, it can be endogenous to other independent variables. Third, the interrelationship can be simultaneous as energy use can also influence household income.

4 Descriptive statistics of these variables can be found in Appendix 2.

5 Results of the VIF tests are in Appendix 3.

where ln_E_{it} is the logarithm of per capita energy expenditure of household i in time t, H and O represent the demographic characteristics and livelihood strategies, A represents the wealth status, and ε is the error term.

For energy transition, we use per capita coal and biomass expenditure (US$), per capita electricity expenditure (US$), share of per capita coal and biomass expenditure in energy expenditure (%), and share of per capita electricity expenditure in energy expenditure (%) as these variables are representative of traditional and modern energy sources. As the consumption of coal and biomass is correlated with the consumption of electricity, the error terms in those regression models are correlated. Therefore, we apply the seemingly (un)related regression (SUREG) to control for the correlations of the error terms (Nguyen et al., 2017). The SUREG regression models are specified as follows:

$$ln\_E_{1it} = \alpha_0 + \alpha_1 H_{it} + \alpha_2 O_{it} + \alpha_3 A_{it} + \varepsilon_{it} \qquad (3a)$$

$$ln\_E_{2it} = \alpha_0 + \alpha_1 H_{it} + \alpha_2 O_{it} + \alpha_3 A_{it} + \varepsilon_{it} \qquad (3b)$$

where ln_E_{1it} is the logarithm of per capita coal and biomass expenditure and ln_E_{2it} is the logarithm of per capita electricity expenditure of household i in time t. We also run the second SUREG regression when ln_E_{1it} and ln_E_{2it} are replaced by the shares of per capita coal and biomass expenditure and of electricity expenditure in energy expenditure.[6]

Regarding energy poverty, the following probit model is used to assess the factors that determine energy poverty:

[6] We check the correlations of the error terms of equations (3a) and (3b) with the Breusch–Pagan tests. The results of these tests show significant correlations (see Appendix 4) and validate our use of SUREG models.

$$Prob(P_{it} = 1) = \gamma_0 + \gamma_1 H_{it} + \gamma_2 O_{it} + \alpha\gamma_3 A_{it} + \tau_{it} \quad (4)$$

where P is the probability that household i is electricity poor or energy-cost poor in year t, H, O and A are defined as in Equation 2 and τ is the error term. In addition, we also run equation 4 for income poverty and consumption poverty to provide a comparative analysis between income poverty, consumption poverty and energy poverty.

4. Results and discussion

4.1 Energy transition

Table 2 presents an overview of energy transition in Vietnam from 2004 to 2016. It is evident that Vietnamese households have been moving from coal and biomass to cleaner energy categories. The share of coal and biomass users fell by 36%, while the shares of gas, oil, and electricity users increased by 47%, 8%, and 7% respectively. Per capita coal and biomass expenditure decreased by about \$3 while per capita expenditures on gas, oil, and electricity increased by about \$17, \$65, and \$41 respectively. The share of coal and biomass expenditure in energy expenditure decreased by 23%, while the figures for oil, gas, and electricity increased. The transition from traditional energy sources (i.e. coal and biomass) to more modern sources (i.e. oil, gas, and electricity) is therefore obvious. This is most likely due to increases in per capita income, which lead to increases in per capita consumption, including per capita energy expenditure.

Table 2: Energy transition in Vietnam from 2004-2016

(Table 2 here)

Table 3 shows energy transition at the regional level. In 2004 except in the South East – the most economically developed region in Vietnam - in all other regions coal and biomass were popularly used by more than 75% of households. During the period 2004-2016, the shares of coal and biomass users decreased significantly. The Red River Delta experienced the most remarkable transition recording a decrease of 58% with all other regions recording at least a 25% reduction. Notably this region has experienced relatively higher economic growth and more rapid urbanization (WB, 2012). The share of gas users increased most. In terms of the per capita energy expenditure, the Red River Delta also has the highest decrease in coal and biomass expenditure and the highest increases in gas, oil, and electricity expenditure. However, per capita coal and biomass expenditure increased in the Northern region by $5.4. This region is the poorest part of the country in terms of income as well as per capita energy expenditure.

Table 3: Energy transition in Vietnam from 2004 - 2016 by region

(Table 3 here)

Table 4 provides the disaggregated data by ethnicity, residential place, and wealth status. Coal and biomass were popularly used by the majority and minority ethnic groups in 2004 with the shares of users being 73% and 93% respectively. However, in 2016, this share was only 32% for the majority ethnic group, but still 77% for the minority ethnic group. The share of gas users for the majority ethnic group also increased more than that for the minority group (53% vs 23% respectively). In terms of electricity, minority households showed stronger growth but mainly due to low access to electricity in 2004 (95% of the majority and 73% of the minority). By 2016, 100% of the majority group and 95% of the minority group had access to electricity. Per capita expenditure for coal and biomass of the minority group increased by about $8 while that of the majority group decreased by about $6. Even though per capita expenditures for gas, oil, and electricity increased, the minority group still spent less than the majority group. This is plausible as in Vietnam ethnic minorities live in remote areas and have much lower living standards. Further details for each year is displayed in Figure 2.

Table 4: Disaggregated energy transition in Vietnam from 2004 - 2016

(Table 4 here)

(Figure 2 here)

Figure 2: Per capita expenditure and share in energy expenditure by ethnicity from 2004- 2016

The reduction in coal and biomass use differs between urban and rural areas. In 2004 about 42% of the urban population and 87% of the rural population in Vietnam used coal and biomass. This fell to 16% and 51% respectively in 2016. Even though the share of coal and biomass users among the rural population decreased more compared to that of the urban population (36% vs 26%), the share of coal and biomass users in rural areas was still high at more than 50% in 2016. Per capita coal and biomass expenditure decreased by only around $1 in rural areas, which is about 5 times less than in urban areas ($4.8). In rural areas, the share of gas users increased by 51% and the per capita oil expenditure increased by $55. This led to the share of per capita oil expenditure in energy expenditure increasing by 18%. Per capita energy expenditure of the urban population increased more than that of the rural population ($143 vs $108). This is associated with a higher increase in per capita consumption of the urban population ($1,813 vs $1,176). Further details for each year is displayed in Figure 3.

(Figure 3 here)

Figure 3: Per capita expenditure and share in energy expenditure by urban vs rural population from 2004 - 2016

The energy transition patterns for consumption poor and consumption non-poor households show an interesting pattern. The shares of coal and biomass users of the poor in 2004 and 2016 were 94% and 86% respectively compared to 64% and 38% for the non-poor. The poor also increased their per capita coal and biomass expenditure by about $7 between 2004 and 2016 while this figure decreased for the non-poor. In 2016 the per capita energy expenditure of the non-poor was 5 times greater than that of the poor (99 US$ vs 20 US$), and the per capita consumption of the non-poor increased 20 times that of the poor (1127 US$ vs 50 US$) (see also Figure 4).

(Figure 4 here)

Figure 4: Per capita expenditure and share in energy expenditure by poor vs non-poor from 2004 to 2016

In summary, we find a pattern of transition from traditional energy to more modern energy sources although there are clear variations between regions, ethnic groups, welfare groups and residential places. At the regional level, the transition is most rapid in the Red River Delta and slowest in the Northern. It is also more rapid for the majority ethnic group, for the non-poor and for the urban population as compared to the ethnic minority group, the poor and the rural population. Notably the poor and ethnic minority households still rely heavily on traditional energy sources such as coal and biomass to meet their energy demands. These patterns are closely associated with differences in socio-economic status among these sub-population clusters in Vietnam (see WB, 2017). This is in line with the current literature on other developing countries which indicates that ethnic minorities, the poor and rural population are often more disadvantageous in many aspects of life than the ethnic majority, the non-poor and urban population (see Barnes et al., 2011; Khandker et al., 2012).

4.2 Energy poverty

Figure 5 describes income poverty, consumption poverty, energy-cost poverty, and electricity poverty from 2004-2016. Undoubtedly, economic growth has led to reductions in income poverty and consumption poverty with the headcount ratio of income poverty decreasing from about 25% in 2004 to only about 7% in 2016. Similarly, the headcount ratio of consumption poverty reduced from about 40% to 3.5% over the same period. A similar trend is observed for electricity poverty, its headcount ratio reducing from 41% to 8%. However, the energy-cost poverty indicator increased by 5% from 2004 to 2016. This is in contrast to our expectation and clearly indicates the need to take into account the capacity to pay for energy use by the Vietnamese population as this increase means that energy has been becoming relatively more expensive to households. Table 5 break-downs at the regional level and shows that while electricity poverty decreased, energy-cost poverty increased except for the most developed region - the South East.

(Figure 5 here)

Figure 5: Income, consumption and energy poverty from 2004 – 2016

Table 5: Income, consumption and energy poverty in Vietnam from 2004 - 2016 by region

(Table 5 here)

Table 6 presents the differences in these poverty indicators between ethnic groups, urban and rural, and the poor and the non-poor. Income poverty, consumption poverty and electricity poverty decreased but energy-cost poverty increased. The ethnic minority is still much poorer than the ethnic majority. The energy-cost poverty of the minority group increased from 39% in 2004 to 49% in 2016. The rural population is also more disadvantaged compared to the urban population in all aspects of poverty. Importantly, the rural population experienced nine times higher energy-cost poverty than the urban population. Similarly, electricity poverty and energy-cost poverty of the poor are higher than those of the non-poor.

Table 6: Disaggregated income, consumption and energy poverty in Vietnam from 2004 - 2016

(Insert Table 6 here)

In summary, on the one hand we find a common pattern that income poverty, consumption poverty and energy poverty have reduced over time along with economic growth and that the poor, ethnic minorities and rural population are also more disadvantageous. On the other hand, we find that energy-cost poverty has increased for the whole population. This implies that energy has become relatively more and more expensive to the Vietnamese households. This might be due to the fact that the energy sector is still dominated by state-owned enterprises. These enterprises are often claimed to be less efficient (WB, 2017). This may reflect the fact that prices of gas, oil and electricity in Vietnam determined by these enterprises are relatively more expensive for respective levels of income.

4.3 Energy inequality

Table 7 presents the Gini coefficients for income, consumption and energy inequalities. Overall, inequality had reduced from 2004 - 2016 in all aspects for which the Gini coefficient increased except coal and biomass consumption. Nevertheless, it can be generalized that (i) consumption is more equal than income and energy expenditure, and (ii) energy expenditure inequality tends to decrease more quickly than income and consumption inequalities.

Table 7: Income, consumption and energy inequality in Vietnam from 2004 - 2016

(Table 7 here)

Table 8: Disaggregated energy inequality in Vietnam from 2004 – 2016

(Table 8 here)

(Figure 6 here)

Figure 6: Lorenz curves of energy consumption expenditure in 2004, 2010 and 2016

However, Table 8 shows that energy inequality increased in the Northern region and for the ethnic minority. Figure 6 displays the Lorenz curves of energy expenditures in 2004 and 2016, which clearly reflect changes in inequalities between coal and biomass expenditure and gas expenditure. The Lorenz curve of gas expenditure has been moving closer to the perfect equality line while that of coal and biomass expenditure has been moving further away. These points indicate that the poorest proportion of minority ethnic households in the Northern region has increased coal and biomass use. This issue needs to be considered by energy policy makers given they are the most disadvantageous group in terms of income, consumption and energy use, and given that their increased use of coal and biomass leads to health and environmental problems.

4.4 Driving factors of energy consumption and energy poverty

Table 9 presents the estimation results of equation 2 (OLS model on per capita energy expenditure), equations 3a and 3b (SUREG models on per capita expenditures and expenditure shares of biomass and coal and electricity), and equation 4 (probit models on income poverty, consumption poverty, electricity poverty and energy-cost poverty). The results in Table 9 validate our earlier descriptive analysis of the disadvantages of minority ethnic groups, the rural population and the heterogeneities among regions. The effects on energy consumption patterns of those belonging to ethnic minorities or those residing in rural areas are similar. Ethnic minorities bear the brunt of the negative effects on per capita energy expenditure as shown by the per capita electricity expenditure and the share of electricity expenditure. It is also the cause of the positive trend in per capita coal and biomass expenditure and the rise in the share of coal and biomass expenditure in overall energy expenditure. Therefore, the ethnic minority group has a higher probability of being poor. This finding is to be expected given ethnic minorities usually reside in remote areas with poor infrastructures (Nguyen, 2012) and have been found to benefit least from economic growth (Baulch et al., 2012). Similarly, our results also confirm that rural households spend less on energy and electricity and more on coal and biomass as compared to urban households. They are as well found to have a higher probability of being poor than their urban counterparts. It is common in developing countries including Vietnam, that rural households are more likely to be poor in terms of income and consumption than urban households. Among the regions, households in the South East are less likely to be poor as this is the most developed region in Vietnam.

Table 9: Factors affecting energy consumption expenditures and poverty

(Table 9 here)

With regard to other factors, the age of household heads has a positive effect on energy expenditure but a negative effect on the probability of being poor. This appears to be due to the fact that, over time, the income of household heads has increased. A higher education level of household heads is associated with higher expenditures for energy and electricity as well as with a higher share of electricity expenditure. The effects of education level are opposite for coal and biomass in terms of both absolute and relative expenditure. Thus, a higher education level of household heads reduces the probability for the households to be poor. A higher education level is usually associated with a higher probability of finding a good job and of having a high income. This finding is consistent with previous studies, for example Rahut et al. (2014) and Bridge et al. (2016). A large household size is associated with a higher per capita coal and biomass expenditure and lower per capita electricity expenditure. This may be because a larger household has a lower per capita purchasing power. This is confirmed by the effects of the share of the dependents on energy use: the more dependent members a household has the lower the per capita energy expenditure and per capita electricity expenditure are. A larger household and a higher number of dependents increase the probability of the household being poor. This result is also consistent with the effect of the durable asset value. This is positively correlated with per capita energy expenditure and electricity expenditure, and negatively correlated with per capita coal and biomass expenditure and with its share in energy expenditure. As a result, a higher value of household durable assets significantly reduces the probability of the household being poor. A household with self-employment activities uses more energy and electricity whilst a household with forest extraction activities uses more coal and biomass. Thus, self-employment reduces the probability of being poor. In addition, extracting forest resources increases the probability of being poor because it does not offer better livelihood alternatives. This is consistent with previous Vietnamese studies (see for example Nguyen et al., 2017) as well as in other neighboring countries such as Laos (see Nguyen et al., 2018) and Cambodia (see Do et al., 2019b).

5. Conclusions

This paper uses a nationally representative household database on energy consumption expenditure in Vietnam from 2004 to 2016 to examine energy transition, energy poverty and energy inequality. The households' energy mix is classified into four categories, coal and biomass, oil, gas, and electricity and disaggregated with respect to region, ethnicity, wealth status and place of residence. We assess the factors that lead to significant differences in terms of energy consumption and energy poverty. Empirical results present several important findings.

First, we find a clear transition from traditional to more modern forms of energy among Vietnamese households but this transition varies across different demographic profiles of households with respect to different energy categories. The more economically developed the region is, the greater the transition. This pattern is similar with regard to ethnicity, household wealth status and place of residence. One exception is with poor and ethnic minority households in the Northern region as they still rely heavily on coal and biomass to meet their energy demands. Indeed their expenditure on traditional coal and biomass forms of energy has increased. Second, we find that while income poverty, consumption poverty and electricity poverty has decreased, energy-cost poverty has increased. This implies the cost of energy is increasing relatively more than income increases. This represents an increasing burden for poor households. Third, we find that energy inequality tends to decrease at a significantly greater rate than income and consumption inequalities. However, the inequality in coal and biomass expenditure is still increasing overtime.

Our findings lead to several policy implications. First, as energy poverty and energy inequality in Vietnam have not been considered important in policy agendas, there have been no specific policies or programs on energy poverty and energy inequality. We therefore recommend the government establish a national program to address these issues. As there are differences in energy consumption, energy poverty and energy inequality among regions, as well as between welfare and ethnic groups and between rural and urban areas, such a national program should be able to capture these heterogeneities. Second, as energy-cost poverty increases, we recommend the government to lower households' energy costs by attracting private investors to participate in energy supply - and particularly electricity - so that prices of energy can be reduced. Third, as education and self-employment have positive effects on energy transition and negative effects on all poverty indicators, promoting them would enhance energy transition and reduce energy poverty. Last, the poor and minority ethnic households are the most disadvantaged group in the population in terms of income, consumption, and clean energy use. They are also more likely to suffer from severer health and environmental consequences due to their increased coal and biomass use. In addition, they face relatively higher costs of energy, which leads to a decrease in consumption of other goods - and consequently undermines their welfare. Therefore, there would appear to be a strong case for providing these groups with added assistance to allow them to transition more rapidly to a higher level of modern energy (e.g. electricity) consumption.

Figure 1

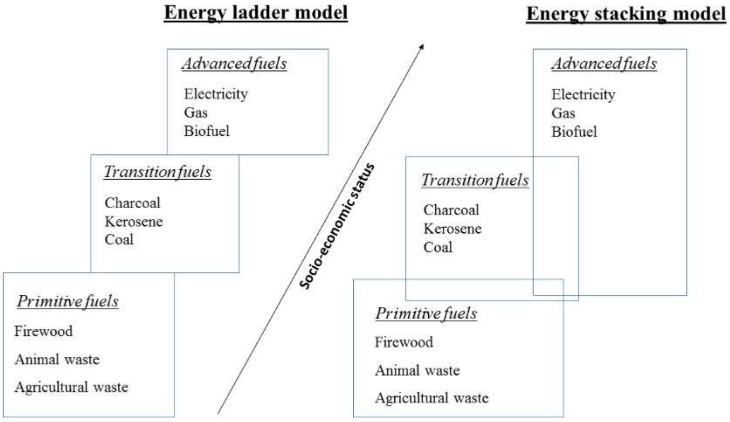

Figure 2

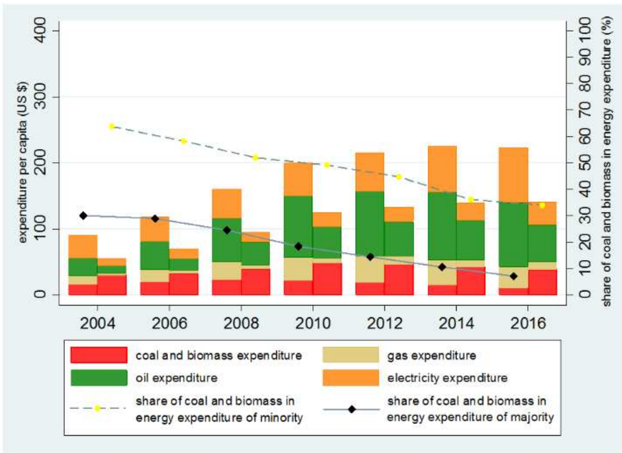

Figure 3

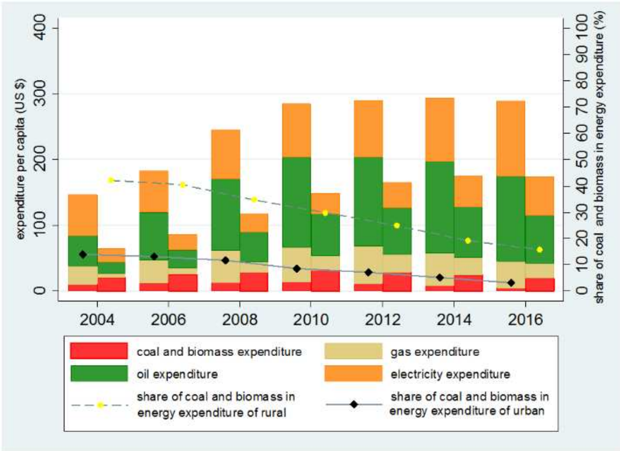

Figure 4

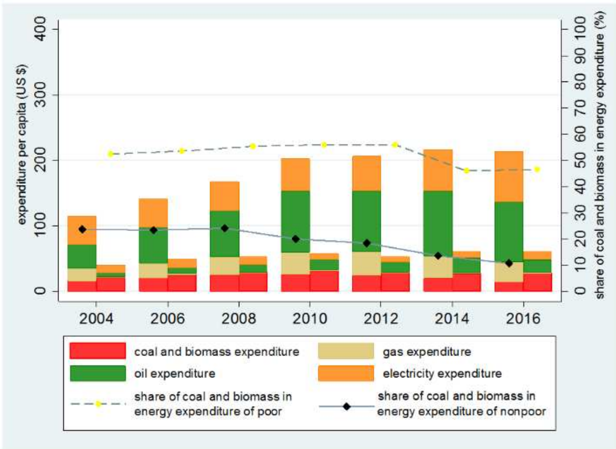

Figure 5

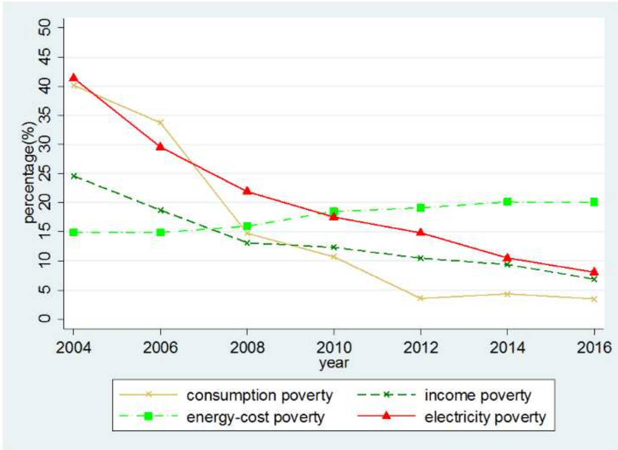

Figure 6

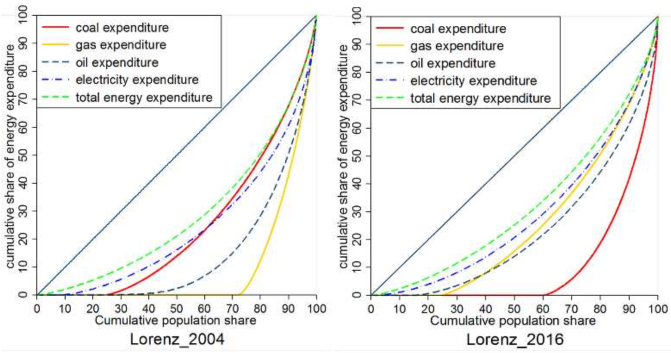

Table 1: Background information on Vietnam's regions

Region	*Area (km^2)*	*Population (1,000 people)*	*Population density (people/km^2)*	*Share of ethnic minority population (%)*	*Share of urban population (%)*	*Annual per capita income (PPP$ 2005)*
	(2015)	*(2015)*	*(2015)*	*(2015)*	*(2011)*	*(2016)*
Red River Delta	21,060	20,925	994	1.5	29.5	6,332
Northern	95,266	11,803	124	56.5	16.2	3,201
Central Coast	95,832	19,658	205	10.1	25.4	3,845
Central Highlands	54,641	5,607	103	36.5	27.2	3,858
South East	23,590	16,127	684	5.6	56.2	7,602
Mekong River Delta	40,576	17,590	434	7.9	23.9	4,530

(Source: calculated from the data of the General Statistics Office)

Table 2: Energy transition in Vietnam from 2004-2016

	2004	2006	2008	2010	2012	2014	2016	∆ 2004-2016
Share of coal & biomass users (%)	76.0	75.0	71.0	62.0	57.0	50.0	40.0	-36.0
Share of oil users (%)	77.0	77.0	84.0	78.0	80.0	84.0	85.0	8.0
Share of gas users (%)	29.0	36.0	46.0	55.0	62.0	69.0	76.0	47.0
Share of electricity users (%)	92.0	95.0	97.0	97.0	97.0	98.0	99.0	7.0
Coal & biomass expenditure/capita (US$)	18.2	22.0	25.2	26.7	23.9	19.8	15.3	-2.8
Oil expenditure/capita (US$)	24.6	39.0	62.1	84.7	89.6	95.9	89.7	65.0
Gas expenditure/capita (US$)	11.4	15.9	23.6	30.4	35.7	32.8	28.7	17.3
Electricity expenditure/capita (US$)	30.8	33.6	39.3	45.0	51.8	61.5	75.0	44.1
Share of coal & biomass in energy expenditure (%)	35.0	34.0	29.0	24.0	20.0	15.0	12.0	-23.0
Share of oil in energy expenditure (%)	21.0	25.0	32.0	36.0	36.0	39.0	37.0	16.0
Share of gas in energy expenditure (%)	8.0	10.0	12.0	15.0	17.0	16.0	15.0	7.0
Share of electricity in energy expenditure (%)	36.0	31.0	27.0	25.0	27.0	30.0	37.0	1.0
Energy expenditure per capita (US$)	85	110	150	187	201	210	209	124
Total consumption per capita (US$)	1056	1178	1583	1852	2426	2344	2470	1414

Table 3: Energy transition in Vietnam from 2004 - 2016 by region

	2004						Δ 2004-2016					
	Red River	Northern	Central Coast	Central Highlands	South East	Mekong River	Red River	Northern	Central Coast	Central Highlands	South East	Mekong River
Share of coal & biomass users (%)	84.0	90.0	79.0	75.0	41.0	75.0	-58.0	-25.0	-32.0	-35.0	-28.0	-31.0
Share of oil users (%)	65.0	73.0	76.0	83.0	89.0	83.0	15.0	14.0	9.0	7.0	4.0	0.0
Share of gas users (%)	24.0	13.0	23.0	34.0	60.0	32.0	66.0	36.0	54.0	32.0	31.0	46.0
Share of electricity users (%)	98.0	84.0	97.0	86.0	95.0	86.0	2.0	10.0	2.0	13.0	5.0	14.0
Coal & biomass expenditure/capita (US$)	14.0	28.5	17.7	17.1	11.8	17.6	-7.4	5.4	-3.5	-5.6	-6.8	-1.8
Oil expenditure/capita (US$)	21.2	14.6	20.5	27.9	56.8	20.0	69.4	58.3	56.7	55.6	92.6	56.1
Gas expenditure/capita (US$)	9.7	5.8	7.5	10.6	28.3	11.6	26.2	14.6	17.0	13.1	14.2	13.8
Electricity expenditure/capita (US$)	36.5	20.1	26.2	21.1	57.6	25.7	62.9	38.4	35.4	28.4	48.4	40.8
Share of coal & biomass in energy expenditure (%)	30.0	53.0	37.0	35.0	15.0	35.0	-25.0	-27.0	-24.0	-23.0	-12.0	-24.0
Share of oil in energy expenditure (%)	16.0	16.0	20.0	28.0	33.0	22.0	16.0	19.0	16.0	16.0	12.0	13.0
Share of gas in energy expenditure (%)	6.0	4.0	6.0	9.0	17.0	11.0	12.0	5.0	9.0	4.0	-1.0	5.0
Share of electricity in energy expenditure (%)	48.0	27.0	37.0	27.0	36.0	32.0	-3.0	2.0	-1.0	4.0	1.0	6.0
Energy expenditure per capita (US$)	81	69	72	77	154	75	151	117	106	91	148	109
Total consumption per capita (US$)	1081	852	916	895	1594	1070	1628	1174	1424	1308	1666	1243

Table 4: Disaggregated energy transition in Vietnam from 2004 - 2016

	2004		2016		Δ 2004-2016	
Ethnic majority vs minority	*Majority*	*Minority*	*Majority*	*Minority*	*Majority*	*Minority*
Share of coal & biomass users (%)	73.0	93.0	32.0	77.0	-41.0	-16.0
Share of oil users (%)	77.0	75.0	86.0	84.0	9.0	9.0
Share of gas users (%)	33.0	6.0	86.0	29.0	53.0	23.0
Share of electricity users (%)	95.0	73.0	100.0	93.0	5.0	20.0
Coal & biomass expenditure/capita (US$)	16.0	30.4	10.3	38.6	-5.7	8.1
Oil expenditure/capita (US$)	27.0	11.6	96.8	56.9	69.8	45.2
Gas expenditure/capita (US$)	13.0	2.6	32.5	11.0	19.5	8.5
Electricity expenditure/capita (US$)	34.4	11.0	83.9	33.8	49.5	22.8
Share of coal & biomass in energy expenditure (%)	30.0	64.0	7.0	34.0	-23.0	-30.0
Share of oil in energy expenditure (%)	22.0	16.0	37.0	37.0	15.0	21.0
Share of gas in energy expenditure (%)	9.0	2.0	16.0	6.0	7.0	4.0
Share of electricity in energy expenditure (%)	39.0	19.0	40.0	23.0	1.0	4.0
Energy expenditure per capita (US$)	90.3	55.6	223.4	140.2	133.2	84.7
Total consumption per capita (US$)	1129	653	2672	1536	1543	883
Urban vs rural	*Urban*	*Rural*	*Urban*	*Rural*	*Urban*	*Rural*
Share of coal & biomass users (%)	42.0	87.0	16.0	51.0	-26.0	-36.0
Share of oil users (%)	83.0	75.0	89.0	84.0	6.0	9.0
Share of gas users (%)	63.0	18.0	91.0	69.0	28.0	51.0
Share of electricity users (%)	99.0	89.0	100.0	98.0	1.0	9.0
Coal & biomass expenditure/capita (US$)	9.7	20.9	5.0	19.8	-4.8	-1.1
Oil expenditure/capita (US$)	46.4	17.5	129.1	72.7	82.6	55.2
Gas expenditure/capita (US$)	28.3	5.9	41.0	23.3	12.7	17.5
Electricity expenditure/capita (US$)	62.1	20.6	114.2	58.0	52.0	37.4

Share of coal & biomass in energy expenditure (%)	14.0	42.0	3.0	24.0	-11.0	-18.0
Share of oil in energy expenditure (%)	27.0	19.0	39.0	37.0	12.0	18.0
Share of gas in energy expenditure (%)	18.0	5.0	16.0	14.0	-2.0	9.0
Share of electricity in energy expenditure (%)	41.0	34.0	42.0	36.0	1.0	2.0
Energy expenditure per capita (US$)	147	65	289	173	143	108
Total consumption per capita (US$)	1658	861	3471	2037	1813	1176
Consumption non-poor vs poor	*Non-poor*	*Poor*	*Non-poor*	*Poor*	*Non-poor*	*Poor*
Share of coal & biomass users (%)	64.0	94.0	38.0	86.0	-26.0	-8.0
Share of oil users (%)	82.0	69.0	86.0	67.0	4.0	-2.0
Share of gas users (%)	45.0	5.0	78.0	12.0	33.0	7.0
Share of electricity users (%)	96.0	85.0	99.0	87.0	3.0	2.0
Coal & biomass expenditure/capita (US$)	16.4	20.8	14.9	27.5	-1.5	6.8
Oil expenditure/capita (US$)	36.6	6.7	92.2	18.0	55.6	11.3
Gas expenditure/capita (US$)	18.3	1.0	29.6	2.5	11.3	1.5
Electricity expenditure/capita (US$)	43.2	12.4	77.2	12.7	34.0	0.4
Share of coal & biomass in energy expenditure (%)	24.0	52.0	11.0	47.0	-13.0	-5.0
Share of oil in energy expenditure (%)	26.0	13.0	37.0	28.0	11.0	15.0
Share of gas in energy expenditure (%)	13.0	2.0	15.0	3.0	2.0	1.0
Share of electricity in energy expenditure (%)	38.0	32.0	37.0	22.0	-1.0	-10.0
Energy expenditure per capita (US$)	115	41	214	61	99	20
Total consumption per capita (US$)	1411	528	2538	578	1127	50

Table 5: Income, consumption and energy poverty in Vietnam from 2004 - 2016 by region

	2004						**∆ 2004-2016**					
	Red River	Northern	Central Coast	Central Highlands	South East	Mekong River	Red River	Northern	Central Coast	Central Highlands	South East	Mekong River
Income poverty (%)	19.1	37.6	30.9	31.0	9.1	19.6	-17.0	-21.2	-22.8	-20.1	-7.7	-15.8
Consumption poverty (%)	39.2	54.8	48.3	46.7	15.1	33.3	-38.3	-47.3	-44.6	-34.9	-14.7	-31.9
Electricity poverty (%)	28.0	59.8	42.0	54.3	17.7	48.3	-27.1	-38.0	-33.4	-40.5	-15.9	-44.4
Energy-cost poverty (%)	8.6	27.2	18.8	18.3	6.8	10.0	1.1	10.0	3.5	6.8	-0.3	9.6

Table 6: Disaggregated income, consumption and energy poverty in Vietnam from 2004 - 2016

	2004		2016		Δ 2004-2016	
Ethnic majority vs minority	*Majority*	*Minority*	*Majority*	*Minority*	*Majority*	*Minority*
Income poverty (%)	18.8	56.6	3.0	25.1	-15.9	-31.5
Consumption poverty (%)	34.1	74.1	0.9	15.6	-33.2	-58.5
Electricity poverty (%)	34.0	82.0	2.4	34.0	-31.6	-48.0
Energy cost poverty (%)	10.5	39.5	13.8	49.0	3.3	9.5
Urban vs rural	*Urban*	*Rural*	*Urban*	*Rural*	*Urban*	*Rural*
Income poverty (%)	7.4	30.2	0.9	9.5	-6.5	-20.7
Consumption poverty (%)	13.1	49.0	0.7	4.7	-12.5	-44.3
Electricity poverty (%)	11.8	51.0	1.3	11.0	-10.5	-40.0
Energy cost poverty (%)	5.0	18.1	5.9	26.2	0.9	8.1
Non-poor vs poor	*Non-poor*	*Poor*	*Non-poor*	*Poor*	*Non-poor*	*Poor*
Income poverty (%)	3.10	56.58	4.85	63.69	1.75	7.11
Consumption poverty (%)	0	100	0	100	0	0
Electricity poverty (%)	21.16	71.48	6.00	64.62	-15.16	-6.86
Energy-cost poverty (%)	2.4	33.5	18.6	61.9	16.2	28.3

Table 7: Income, consumption and energy inequality in Vietnam from 2004 - 2016

Gini coefficient	2004	2006	2008	2010	2012	2014	2016	∆ 2004-2016
Income inequality	0.40	0.41	0.44	0.43	0.41	0.40	0.39	-0.01
Consumption inequality	0.34	0.35	0.35	0.34	0.33	0.32	0.32	-0.02
Energy consumption inequality	0.43	0.43	0.42	0.44	0.40	0.37	0.37	-0.06
Coal & biomass consumption inequality	0.52	0.53	0.56	0.67	0.69	0.74	0.79	0.27
Oil consumption inequality	0.71	0.69	0.63	0.61	0.59	0.53	0.54	-0.17
Gas consumption inequality	0.81	0.76	0.69	0.65	0.59	0.53	0.49	-0.32
Electricity consumption inequality	0.52	0.50	0.50	0.53	0.47	0.45	0.43	-0.09

Table 8: Disaggregated energy inequality in Vietnam from 2004 – 2016

Gini coefficient	2004	2006	2008	2010	2012	2014	2016	Δ 2004-2016
Region								
Red River	0.47	0.43	0.42	0.45	0.39	0.35	0.34	-0.13
Northern	0.37	0.39	0.39	0.43	0.40	0.38	0.38	0.01
Central Coast	0.40	0.39	0.40	0.39	0.38	0.36	0.36	-0.04
Central Highlands	0.40	0.40	0.35	0.36	0.42	0.38	0.35	-0.05
South East	0.38	0.39	0.39	0.42	0.36	0.32	0.33	-0.05
Mekong	0.40	0.41	0.40	0.43	0.37	0.35	0.35	-0.05
Non-poor vs poor								
Poor	0.38	0.38	0.39	0.41	0.39	0.36	0.36	-0.02
Non-poor	0.29	0.29	0.29	0.31	0.29	0.30	0.28	-0.01
Urban vs rural								
Rural	0.38	0.39	0.38	0.41	0.38	0.35	0.34	-0.04
Urban	0.38	0.38	0.39	0.40	0.36	0.33	0.35	-0.03
Ethnic majority vs minority								
Majority	0.43	0.42	0.41	0.42	0.38	0.35	0.35	-0.08
Minority	0.38	0.40	0.39	0.45	0.42	0.41	0.40	0.02

Table 9: Factors affecting energy consumption expenditures and poverty

	OLS	SUREG		SUREG		Probit			
	Per capita energy expenditure (ln)	Per capita electricity expenditure (ln)	Per capita coal and biomass expenditure (ln)	Share of electricity in energy expenditure (%)	Share of coal and biomass in energy expenditure (%)	Consumption poverty	Income poverty	Electricity poverty	Energy-cost poverty
Age of HH head (years)	0.00***	0.02***	0.02***	0.00***	0.00	-0.01***	-0.01***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Ethnic minority (1=yes)	-0.15***	-1.69***	0.99***	-0.06***	0.12***	0.66***	0.60***	0.80***	0.43***
	(0.01)	(0.04)	(0.09)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)
Primary school of HH head (1=yes)	0.18***	0.91***	-0.79***	0.01***	-0.06***	-0.38***	-0.28***	-0.34***	-0.14***
	(0.01)	(0.03)	(0.08)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)
Secondary school of HH head (1=yes)	0.27***	1.27***	-1.21***	0.02***	-0.09***	-0.60***	-0.49***	-0.56***	-0.32***
	(0.01)	(0.04)	(0.08)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)
High school of HH head (1=yes)	0.58***	1.47***	-3.66***	0.02***	-0.15***	-1.06***	-0.94***	-0.91***	-0.74***
	(0.01)	(0.04)	(0.09)	(0.00)	(0.00)	(0.03)	(0.03)	(0.03)	(0.02)
HH size (no. of persons)	-0.08***	-0.16***	0.09***	-0.01***	-0.01***	0.17***	0.10***	0.16***	0.03***
	(0.00)	(0.01)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
HH durable asset value (US$) (ln)	0.01***	0.03***	-0.04***	0.00***	-0.00***	-0.02***	-0.03***	-0.02***	-0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Share of the dependent in HH size (%)	-0.43***	-0.66***	-0.22**	0.04***	0.06***	1.05***	0.98***	0.53***	0.66***
	(0.01)	(0.05)	(0.10)	(0.00)	(0.00)	(0.03)	(0.03)	(0.03)	(0.02)
Self-employment (1=yes)	0.09***	0.32***	-1.21***	0.03***	-0.04***	-0.28***	-0.39***	-0.31***	-0.27***
	(0.01)	(0.03)	(0.06)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.01)
Forest extraction (1=yes)	-0.14***	-0.79***	3.59***	-0.04***	0.14***	0.31***	0.31***	0.47***	0.29***
	(0.01)	(0.04)	(0.08)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)
Rural (1=yes)	-0.36***	-0.66***	4.35***	-0.04***	0.10***	0.62***	0.49***	0.58***	0.47***
	(0.01)	(0.03)	(0.07)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)
Red river delta (1=yes)	-0.50***	-0.40***	5.25***	0.06***	0.11***	0.94***	0.68***	0.42***	0.29***
	(0.01)	(0.04)	(0.10)	(0.00)	(0.00)	(0.04)	(0.04)	(0.03)	(0.03)
Northern (1=yes)	-0.37***	-0.86***	5.83***	-0.01***	0.16***	0.64***	0.67***	0.59***	0.55***

	(0.01)	(0.05)	(0.11)	(0.00)	(0.00)	(0.04)	(0.04)	(0.03)	(0.03)
Central coast (1=yes)	-0.52***	-0.39***	4.56***	0.00	0.11***	0.96***	0.85***	0.57***	0.55***
	(0.01)	(0.04)	(0.10)	(0.00)	(0.00)	(0.04)	(0.03)	(0.03)	(0.03)
Central highlands (1=yes)	-0.38***	-0.44***	3.22***	-0.03***	0.05***	0.71***	0.58***	0.47***	0.37***
	(0.01)	(0.06)	(0.13)	(0.00)	(0.00)	(0.04)	(0.04)	(0.04)	(0.03)
Mekong river delta (1=yes)	-0.46***	-0.60***	4.14***	0.01***	0.10***	0.45***	0.44***	0.56***	0.22***
	(0.01)	(0.04)	(0.09)	(0.00)	(0.00)	(0.04)	(0.03)	(0.03)	(0.03)
2006 (1=yes)	0.22***	0.46***	0.21**	-0.05***	-0.00	-0.13***	-0.20***	-0.35***	0.05*
	(0.01)	(0.04)	(0.10)	(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.03)
2008 (1=yes)	0.51***	0.82***	-0.25**	-0.09***	-0.05***	-0.97***	-0.47***	-0.65***	0.14***
	(0.01)	(0.05)	(0.10)	(0.00)	(0.00)	(0.02)	(0.03)	(0.02)	(0.02)
2010 (1=yes)	0.47***	0.25***	-0.40***	-0.12***	-0.01***	-0.80***	-0.00	-0.48***	0.59***
	(0.01)	(0.06)	(0.13)	(0.00)	(0.00)	(0.03)	(0.04)	(0.03)	(0.03)
2012 (1=yes)	0.60***	0.55***	-1.59***	-0.10***	-0.06***	-1.62***	-0.15***	-0.70***	0.60***
	(0.01)	(0.06)	(0.13)	(0.00)	(0.00)	(0.04)	(0.04)	(0.03)	(0.03)
2014 (1=yes)	0.66***	0.82***	-2.76***	-0.07***	-0.11***	-1.44***	-0.19***	-0.97***	0.67***
	(0.01)	(0.06)	(0.13)	(0.00)	(0.00)	(0.04)	(0.04)	(0.03)	(0.03)
2016 (1=yes)	0.65***	1.13***	-4.40***	-0.01***	-0.13***	-1.57***	-0.39***	-1.17***	0.68***
	(0.01)	(0.06)	(0.13)	(0.00)	(0.00)	(0.04)	(0.04)	(0.04)	(0.03)
Constant	5.09***	2.58***	-9.72***	0.35***	0.17***	-1.80***	-2.16***	-1.50***	-1.97***
	(0.02)	(0.09)	(0.19)	(0.00)	(0.01)	(0.06)	(0.06)	(0.05)	(0.05)
Observations	64,605	64,605	64,605	64,605	64,605	64,605	64,605	64,605	64,605
R2	0.4700	0.2296	0.3412	0.2289	0.4397				
F(22, 64582)	2602.93								
Pseudo R2						0.4123	0.2941	0.3576	0.1911
Chi2		19248.61	33455.91	19172.56	50703.72	23161.16	15109.98	23400.17	11518.96
Prob.> F / Chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; HH: household

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