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WHY IS ENERGY ACCESS NOT ENOUGH FOR CHOOSING CLEAN COOKING FUELS? SUSTAINABLE DEVELOPMENT GOALS AND BEYOND

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Abstract

The transition to sustainable energy requires an assessment of drivers of the use of clean and dirty fuels for cooking. Literature highlights the importance of access to modern fuel for switching from dirty fuels. Though access to cleaner fuels such as electricity promotes clean fuel use, it does not necessarily lead to a complete transition to the use of modern fuels. Households continue using traditional fuels in addition to modern fuels. The main objective of this paper is to explain the choice of dirty cooking fuels even when access to electricity is provided. We use nationally representative household survey data to study the household energy use decisions in three middle-income countries, India, Kazakhstan, and the Kyrgyz Republic. The study discusses the role of access to natural gas, free fuel, convenience or multi-use of fuels determined by the heating system installed, built-in environment, and other socioeconomic factors in household fuel choice for cooking. The results show that access to natural gas increases the likelihood of opting for natural gas, while the availability of free fuel in rural areas and the coal-based heating system promote the use of solid fuels.

Keywords: cooking fuel, fuel choices, energy access, multiple fuel use, Sustainable Development Goals (SDGs)

JEL Classification: Q41, Q31, Q48

Contents

1. INTRODUCTION

Ensuring access to affordable, reliable, sustainable, and modern energy for all by 2030 is the seventh of the 17 UN Sustainable Development Goals (Resolution of the General Assembly on 25 September 2015). Fuel choices for cooking are not only important for SDG 7.1—"to ensure universal access to affordable, reliable, and modern energy services"—but are highly important to achieve other goals such as good health and wellbeing (SDG 3) and climate action (SDG 13). There is strong evidence that the combustion of solid fuels in inefficient stoves leads to the release of suspended particulate matter, carbon monoxide, polyaromatic hydrocarbons, polyorganic matter, and formaldehyde that have adverse effects on health (Kankaria, Nongkynrih, and Gupta 2014). Cooking with solid fuels presents high health risks, especially for women and children. Household choice of fuel also contributes to climate change due to greenhouse gas (GHG) emissions (Smith and Haigler 2008). Recognizing the above facts, SDG 7 includes SDG 7.1: to ensure universal access to affordable, reliable, and modern energy services by 2030.

Developing countries are working hard toward this gasification and electrification target, with commendable results in the past few years. However, effective public policy aiming to increase large-scale access to clean fuels needs to be coupled with an effective transition. This has been a concern of many middle-income countries, including India, Kazakhstan, and the Kyrgyz Republic, where 'dirty' solid fuels are still used, especially in rural areas (Gassmann and Tsukada 2014; Kerimray et al. 2018; Ravindra et al. 2019). In India, 78% of rural households rely on solid biomass for cooking due to poor quality of life, equity, and economy (Ravindra et al. 2019). Only 6% of surveyed households in Kazakhstan were using solid fuels for cooking. Widespread power cuts in the Kyrgyz Republic could be one of the factors limiting households from switching fully to cooking with electricity in the Kyrgyz Republic. Many areas in India, Kazakhstan, and the Kyrgyz Republic suffer from poor air quality, and the wide use of solid fuel by households contributes to outdoor and indoor air pollution (Kankaria, Nongkynrih, and Gupta 2014; Kenessary et al. 2019; UNDP 2012b). CO_2 and $PM_{2.5}$ are major risk factors for lung cancer in the Southeast Asia region: deployment of renewable energy can reduce air pollution and, consequently, reduce the prevalence of lung cancer (Taghizadeh-Hesary and Taghizadeh-Hesary 2020). Similarly, the study by Rasoulinezhad, Taghizadeh-Hesary, and Taghizadeh-Hesary (2020) conducted in the Commonwealth of Independent States (CIS, including Kazakhstan and the Kyrgyz Republic, among other countries) depicted that CO_2 emissions (and fossil fuel consumption) in the CIS region had a positive relationship with mortality from cardiovascular disease, diabetes mellitus, cancer, and chronic respiratory disease. The International Energy Agency (2020) estimated that switching from coal to gas in the residential sector of Kazakhstan by 2030 would result in the reduction of emissions of $PM_{2.5}$ by 88% from the 2018 level, as well as CO (–78%), NOx (–41%), SOx (–77%), and CO_2 (-93%). Transition to clean cooking is imperative due to its multiple co-benefits, primarily health and climate (Goldemberg et al. 2018). To design efficient policies targeting the transition to clean energy use, quantitative assessments are needed for a better understanding of the determinants of households' fuel choice.

Most previous studies on the determinants of household cooking fuel choice focus on socioeconomic characteristics (e.g., income, gender, and age of household head, dwelling, and cookstove), behavioral and cultural factors, and external factors such as availability of fuels, physical environment, market conditions, and government policies (Alem et al. 2016; Brooks et al. 2016; Timilsina 2014). Countries have unique characteristics which result in different energy consumption and different determinants

of fuel mix (Lenzen et al. 2006). Hence, there is no one-size-fits-all recipe for energy transition or energy ladder, a theory suggesting that a transition from traditional to modern fuels is mainly driven by economic factors, as these factors can differ across regions, countries, and climatic zones, thus highlighting the complexity of fuel switching (Karimu, Mensah, and Adu 2016; Lenzen et al. 2006; Martey 2019). Moreover, higher incomes do not necessarily lead to a complete transition to the use of modern fuels. Households tend to continue using traditional fuels in addition to modern fuel, showing 'fuel stacking' behavior (Choumert-Nkolo, Combes Motel, and Le Roux 2019; Lay, Ondraczek, and Stoever 2013; Masera, Saatkamp, and Kammen 2000; Quinn et al. 2018; Shankar et al. 2020).

The main objective of this paper is to assess the role of access to natural gas, free fuel, convenience or multi-use of fuels determined by the heating system installed, built-in environment, and socioeconomic factors on the choice of cooking fuels or cookstove. To have a wider impact, we tried to accommodate diverse population density, availability of resources, geographical and climatic characteristics, and socioeconomic aspects. However, we were constrained by comparative micro-data availability at a country level. The scope of the study has been narrowed down to three countries, two from Central Asia and one from South Asia, namely India, Kazakhstan, and the Kyrgyz Republic. Kazakhstan and the Kyrgyz Republic are selected as examples of countries with almost total energy access—i.e., electrification. Although India has not achieved 100% energy access, our sample is limited only to households with access to electricity.

The remainder of the paper is structured as follows. Section 2 reviews the extant literature. Section 3 provides background information for the three countries. Sections 4 and 5 section present the data and empirical strategy. Section 6 discusses the results. Section 7 concludes with a summary of the results and policy implications.

2. LITERATURE REVIEW

There is no universally agreed definition of 'clean' cooking fuel. Conventionally, the term is used to refer to cooking solutions that do not generate indoor air pollution (e.g., particulate matter and carbon monoxide) or, if that occurs, the air pollution concentration is significantly low. Also, such cooking practices do not contribute to outdoor air pollution in the form of black carbon emissions. Having been subsidized for over three decades, liquefied petroleum gas (LPG) is now a predominantly clean cooking fuel in urban India, 94% of households having connections, according to Pradhan Mantri Ujjwala Yojana (PMUY)[1] (Patnaik, Tripathi, and Jain 2019). In Kazakhstan and the Kyrgyz Republic, natural gas or electricity is treated as a predominantly used cooking fuel.

There is a wide range of studies focusing on the different factors that influence households' choice of cooking fuel. Prominent among these factors are economic change, change in taste and preference for energy choice, technological change in energy sources, energy carrier availability, and/or shifts in the supply of energy options and their prices (Alem, Hassen, and Köhlin 2014; Alem et al. 2016; Brooks et al. 2016; Gebreegziabher et al. 2018). Cooking with solid fuels is intertwined with structural elements, such as established traditions, traditional income-generating practices, gender norms, and a sense of belonging. These factors profoundly dominate

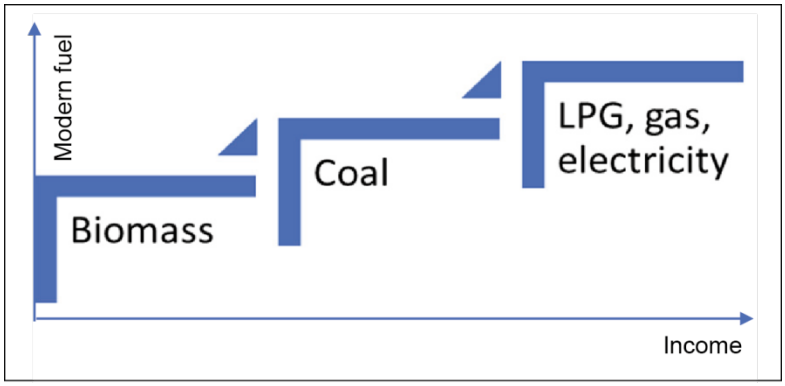
[1] PMUY is a program launched by the Prime Minister of India, Narendra Modi, on 1 May 2016 to distribute 50 million LPG connections to female-headed households below the poverty line.

households' decision to continue using solid fuels despite the availability and adoption of modern alternatives (Malakar, Greig, and van de Fliert 2018). Hanna and Oliva (2015), in their study based on a natural experiment, found that an increase in income does not help households switch to a better cooking source, and many of the target households switched to a worse but more readily available source—assets in the form of livestock produced a cheap source of dung for use as fuel.

Studies on India show that affordability is a great factor in guaranteeing widespread uptake of LPG use, especially in rural areas (Gould and Urpelainen 2018; Kumar, Kaushalendra Rao, and Reddy 2016). Recent programs, such as PMUY, facilitating LPG access and subsidies for the poor, promoted the use of LPG among wider circles of the population, but affordability remains an impediment to complete transition to clean fuels (Gould and Urpelainen 2018). In most countries, cooking fuels include traditional solid fuel, such as wood and charcoal, as well as modern fuels such as LPG, electricity, and natural gas. The choice of solid fuel raises most concerns, as such fuel causes both indoor and outdoor pollution. Although access to electricity is improving—for example, in Kazakhstan and the Kyrgyz Republic it is around 100%—solid fuels are still used for cooking to varying degrees.

Most empirical studies include the following socioeconomic factors as determinants of cooking fuel choice: household income and size; household head's age, education, and gender; household location (rural or urban); and fuel availability. Fuel price is an important determinant of fuel demand. However, not many studies include fuel prices in their empirical analysis due to data scarcity (Alem et al. 2016). Household (and household head) characteristics include household income and size, as well as the household head's age, education, and gender. Income is one of the main determinants of fuel choice. The impact of income on fuel choice is explained by the energy ladder hypothesis (Leach 1992), which states that as income increases, households use more reliable, modern, cleaner, and efficient fuel (Figure 1). Household income is usually measured as total consumption expenditure per capita.

Figure 1: Energy Ladder



Source: Own elaboration using Amoah (2019).

Household size is a key determinant of fuel choice (Alem et al. 2016). As household size increases, demand for energy increases. Households switch to cheaper energy sources to satisfy the increased energy demand (Ngui et al. 2011). Also, larger households with more children and more females have a lower opportunity cost for collecting biomass (Alem et al. 2016; Heltberg 2004; Rao and Reddy 2007). Household heads with better education are more aware of the impact on health of indoor pollution caused by traditional fuels (Alem et al. 2016) and hence opt out of the use of dirty fuel.

Households' location in rural or urban areas determines access to fuels. For example, biomass is more accessible in rural than in urban areas. Fuel availability and accessibility are very important for the choice of cooking fuel (Alem et al. 2016; Gupta and Köhlin 2006). Modern fuels such as natural gas and electricity are not widely available and accessible to households in developing countries due to the lack of infrastructure. The availability of cleaner cookstoves, such as LPG, electric, or gas cookstoves, is another important determinant (Brooks et al. 2016). A systematic literature review on the determinants of cooking fuel choice is provided in the literature (Lewis and Pattanayak 2012; Muller and Yan 2018; Timilsina 2014).

Most literature studying the choice of cooking fuel use the multinomial logit method (MLM). The multinomial logit model allows us to accommodate the use of more than one fuel type, which causes fuel stacking behavior (Muller and Yan 2018). This is important because many households use a combination of several cooking fuels and cookstoves. Various studies have employed MLM to explore the determinants of households' cooking fuel choice.

For the Kyrgyz Republic, only a few studies present a profile of household energy consumption and households' fuel choice (Gassmann and Tsukada 2014; Sabyrbekov and Ukueva 2019). Sabyrbekov and Ukueva (2019) argued that high income itself does not guarantee the use of clean energy, but rather results in the consumption of multiple fuels. Conversely, access to gas and education leads to the transition to clean energy. Sabyrbekov and Ukueva (2019) focuses on total household energy demand, while the focus of our paper is on the energy demand for cooking. To the best of our knowledge, no studies have explored the determinants of household energy demand in Kazakhstan. Previous studies have presented an energy consumption profile of households in Kazakhstan using a household living conditions survey conducted in 2013, covering 12,000 households) (Kerimray et al. 2018). The empirical literature on cooking fuel choice in India is more abundant (Brooks et al. 2016; Menghwani et al. 2019; Ravindra et al.,2019). Cooking fuel preferences in India in general are significantly determined by socioeconomic and cultural factors (Ravindra et al. 2019).

3. BACKGROUND

Cooking fuel is a basic energy need of households. Despite some progress in the reduction of income poverty and in providing wider access to clean energy (e.g., electrification), progress in the energy transition to cleaner fuels has not been uniform globally. Paradoxically, over 17 years in Kazakhstan and the Kyrgyz Republic, the share of dirty fuels (e.g., coal) in the total energy consumption by households has been rising, while the share of cleaner fuels (electricity and gas) has grown slowly or even declined. In contrast, there has been a rise in the share of electricity in India from 5% in 2000 to 15% in 2017, although the share of gas remains low (1%).

Despite almost universal access to electricity, solid fuels are used for heating and cooking needs by 60% of households in the Kyrgyz Republic (Gassmann and Tsukada 2014) and by 40% of households in Kazakhstan (Kerimray et al. 2018). In Kazakhstan, solid fuels are rarely used for cooking, electricity, natural gas, and LPG being more commonly used (Kerimray et al. 2018). In Kazakhstan, only 6% of surveyed households used solid fuels for cooking, while 40% of households used electricity, 29% used natural gas, and 25% used LPG (Table A3.2 in Appendix A). In the Kyrgyz Republic, 37% of surveyed households used solid fuels, 14% used LPG, and 47% used electricity (Table A3.3 in Appendix A). Widespread power cuts in the Kyrgyz

Republic (Dikambayev 2019) may explain why households do not completely switch to cooking using electricity. In contrast, power outages in Kazakhstan are rare.

In Kazakhstan and the Kyrgyz Republic, official strategic documents mostly focus on the development of the supply-side energy infrastructure, while, to the best of our knowledge, there are no specific programs targeted at promoting the transition to clean energy use at the household level. Through fuel and energy development strategies and green economy development programs that envisage the development of energy-generating capacity via the construction of new power plants, governments facilitate the use of renewable energy sources, and increase energy efficiency and the use of energy-saving technologies. In Kazakhstan, there has been substantial progress in providing access to a gas network over the last seven years. The share of the population with access to a piped gas network increased from 30% in 2013 to 52% in 2019 (KazTransGas 2019). Completion of construction of the Saryarka gas pipeline in 2019 is expected to provide natural gas access to the gas-deficient Central Kazakhstan, which has a population of 2.7 million people (Karimova 2019). The Kyrgyz Republic government, in turn, aims to ensure access to natural gas to 60% of the population by 2030 (Gazprom 2015). Increased access to the gas network will likely contribute to energy transition in Kazakhstan and the Kyrgyz Republic; however, more support may be needed for low-income households to ensure affordability and greater adoption of natural gas. In Kazakhstan, despite the availability of the network gas in a neighborhood, some households continue to rely on coal due to the relatively high cost of connection, the high cost of a gas boiler, or for other reasons. Moreover, there are no specific programs in Kazakhstan aiming to subsidize the cost of connecting to a gas pipeline or purchasing a gas boiler. Other measures adopted in some countries include a ban on coal-burning by households (particularly in urban areas), which was found to be particularly effective in reducing the air pollution level (Dockery et al. 2013). For Kazakhstan and the Kyrgyz Republic, applying a coal ban as a policy instrument may require financial support programs for low-income households.

In India, there are specific programs for the transition to clean energy use at the household level. The most prominent effort by the Indian government in terms of improving access to clean cooking energy is the PMUY, launched in 2016. It has provided subsidized LPG connections to over 70 million households in 700 districts (Ministry of Finance of India 2019). Previously, the government has also attempted to improve access to LPG by expanding the distributor network in rural areas through the Rajiv Gandhi Gramin LPG Vitaran Yojana. This scheme helped increase the share of rural distributorship from 14% since its launch in 2009–2010 to over 40% in 2016–2017 (Dubey 2017). However, the government's strategy for increasing LPG usage must go beyond expanding the distribution of connections: it must also promote the sustained use of LPG as primary cooking fuel. Fewer than 5% of the sample households used LPG exclusively (Jain et al. 2015). Only 22% of the sample households reported using LPG, yet more than one-third of them did not use it as their primary cooking fuel, indicating a high level of fuel stacking behavior (Patnaik et al. 2017).

4. DATA AND DESCRIPTIVE STATISTICS

To study the factors affecting cooking fuel choices we use household-level information collected through three different household surveys in India, Kazakhstan, and the Kyrgyz Republic. The data for India derive from the household consumer expenditure survey conducted by the National Sample Survey Organization (2012). We use the latest wave of this survey (68th round), collected during 2011–2012. This nationally representative survey covered all geographical areas of the country, collecting

information on a total of 101,662 households. In addition to household and demographic characteristics, the survey collected detailed data on consumption expenditure on various items, including different categories of fuel. The survey has information on households' primary cooking fuel. In the sample, 29.6% of rural and 74.6% of urban households reported LPG as their primary cooking fuel (Table A1.1 in Appendix A). To maintain comparability across the selected countries, we focus on only 87% of households for further analysis, considering only those households that have access to electricity. The sample for analysis includes a total of 85,601 households (55.3% rural and 44.7% urban) (Table A2.1 in Appendix A). The average size of the household is 4.5 members. Around 33% of households had at least one regular salary earner; 84% of households lived in their own house; and 37% reported access to free fuel, comprising free collection from common property resources.

Kazakhstan

For Kazakhstan, we use microdata from the Household Fuel and Energy Consumption Survey for 2017, collected by Committee of Statistics of the Republic of Kazakhstan (2017). This is the first survey implemented by Kazakhstan to collect data on fuel use. The distribution of the cross-sectional dataset (21,000 households) across five regions of Kazakhstan is in proportion to the population distribution. The survey includes information on household energy choice for cooking, type of settlement, year of housing construction, housing area, number of residents, consumption of fuel types and energy, and other information related to the user's equipment for space heating, cooking, and water heating. The limitation of this dataset is that it does not have information related to the socioeconomic and demographic characteristics of households. Around 66% of the total sample is drawn from an urban area (Table A1.2 in Appendix A). The average size of the household is 3.2 members; the average area of the house is 69 m^2. Of the total sample, 59% live in apartments. Access to free fuel is reported by only 4% of the sample.

The Kyrgyz Republic

For the Kyrgyz Republic, data from the 2016 Life in the Kyrgyz Republic survey are used. This survey was conducted by the Leibniz Institute of Vegetable and Ornamental Crops (IGZ), the Food and Agriculture Organization of the United Nations (FAO), the International Food Policy Research Institute (IFPRI), and the University of Central Asia (International Data Service Center 2016). Data include widespread information on a household level and are representative at the national level. The survey includes around 3,000 households. However, due to missing data, the initial sample size is reduced to 2,521 households. Overall, the sample size may vary depending on the availability of data for the outcome and explanatory variables.

Along with the characteristics of the household and household head, information on household expenditure on the main energy types is used. In particular, the survey records household expenditure on electricity, coal, petrol, and gas. However, it does not identify the quantity of energy consumed. Price information for each region for each type of energy source was used to convert expenditure into the physical quantity of each energy type. However, there is no available information with detailed data on energy prices at a regional level: hence energy prices for the regional level are obtained using the consumer price index for the item 'energy, gas, and other types of fuel' for each region and the average price at a national level. Petrol is excluded in our estimation since it is mainly used for transportation and not for cooking or heating purposes. The sample consists of 62% rural households (Table A1.3 in Appendix A). The average household size is 5.26 persons. The average number of rooms in the

dwelling unit is 3.6. Around 71% of the sample is represented by male-headed households, and 52% of the heads have acquired education up to secondary level.

5. EMPIRICAL STRATEGY

Due to the difference in the variables collected in each of the surveys, we model household fuel choice for cooking for each country using close but slightly differentiated explanatory variables. Uncovering households' cooking fuel choices is empirically challenging. As highlighted by other studies despite policies aiming to improve the availability of cleaner fuel (natural gas and LPG), demand-side issues concerning its adoption and sustained and exclusive use remain an issue in developing countries (Kumar, Kaushalendra Rao, and Reddy 2016).. Given that household adoption and sustained use of clean cooking fuel is a function of economic and social determinants, it needs more attention (Lewis and Pattanayak 2012). In our paper, we model two cooking fuel choices: the dominant fuel which is the primary source of cooking, and the fuel stacking behavior of the households. We therefore model a combination of dirty fuel with clean cooking fuel.

Identification of Dominant Cooking Fuel

We model the dominant cooking fuel in the case of India and the Kyrgyz Republic using Eq. 1.

$$\Pr(fuel\ type) = \beta_0 + \beta_1 household_{char} + \beta_2 convenience + \beta_3 affordability + \beta_4 \text{accessibility} + \beta_5 \text{built\_environment} + \beta_6 \text{tenure\_status} + \varepsilon \quad (1)$$

Our dataset for these two counties included information on the most dominant cooking fuel in the household. However, this information was lacking in the dataset from Kazakhstan. We modeled the most used fuel using multinomial logit regression. The multinomial logistic regression model is an extension of binary logistic regression and is effective where there is a polychotomous categorical dependent variable. In our data, the choice of dominant fuel takes a value 1 to 4 for the categories LPG (base category), solid fuel, kerosene, and others (including electricity). In the case of the Kyrgyz Republic, the value of the dependent variable varies from 1 to 5 for solid fuel, gas pipeline, gas cylinder, electricity, and others (as a base category). The explanatory variables are divided into six categories; household characteristics, convenience, affordability, accessibility, built environment, and tenure status. The details of the indicators used in each category are discussed in Table 1.

Identification of Multiple Fuel Use

To study the fuel stacking behavior of households we need to study the distribution of fuel choice for cooking across households. For this, we construct the dependent variable as a combination of the clean fuel with dirty fuels. A mix of fuels is identified based on the pairwise fuel consumption matrix for each country (Tables A3.1–A3.3 in Appendix A). In India, around 1,200 households in rural areas use LPG with kerosene; for urban areas, the figure is 10,776. The matrix reports a high incidence of LPG and wood combination in rural India—i.e., 12,335 households. In Kazakhstan, the incidence of LPG in combination with electricity is 1,131, and a combination of LPG and solid fuel is used by 910 households in rural areas. A similar trend is observed in fuel combinations in the urban sample. In the Kyrgyz Republic, the most dominant

combination of fuel is coal and electricity, used by 1,323 and 471 households, respectively, in the rural and urban samples.

We use the following equation to model the factors affecting different fuel mixes with the most ideal clean fuel across the three countries. Using MLM, we model the factors affecting different fuel mixes in the three countries. We modeled the probability of adoption of a particular combination of fuels for all the three countries (Eq. 2). Here, the dependent variable is the ordinal value assigned to each pair of fuels. The explanatory variables included are as in Eq. (1).

$$\Pr(fuel\ combinations) = \beta 0 + \beta 1 household_{char} + \beta 2 convenience + \beta 3 affordability + \beta 4 \text{accessibility} + \beta 5 \text{built}_{\text{environment}} + \beta 6 \text{tenure\_status} + \varepsilon \quad (2)$$

The factors affecting adoption and sustained use of cooking fuel in the regression are classified into the following six broad categories.

Table 1: Variables

	Variables		
Classification	**India**	**Kazakhstan**	**Kyrgyz Republic**
Household characteristics	Education of the head of the household	Household size	Education of the head of the household
	Age of the head of the household		Gender of the head of the household
	Gender of the head of the household		
	Household size		
	Social group		
Convenience/ Multiuse	Free fuel	Heating system	Heating system
		Free fuel	
Affordability	Salaried income	Fuel prices	Fuel prices
	Monthly per capita expenditure		Monthly per capita expenditure
Accessibility	Access to LPG	Access to natural gas	Access to natural gas
Built environment		Apartment	Number of dwelling rooms
Tenure status	Ownership of the house	Ownership of the house	

In India, the list of regressors includes a log of monthly per capita expenditure (MPCE), education characteristics, age of household head, gender of household head, household size, a dummy variable that controls whether a household is a regular salary earner, and information about social groups, access to free fuel, and access to LPG.

In Kazakhstan, the list of regressors includes prices of fuel, dwelling characteristics such as total area of the dwelling unit and whether a household resides in an apartment/dormitory versus a separate house, access to natural gas, access to free fuel, and the type of a heating system installed in the premises of a household. The household survey does not have information about the prices of fuel and therefore we use regional prices (16 prices in total). We do not have information about household income or household expenditures, so we use the total area of a dwelling unit as a proxy for wealth.

Finally, in the Kyrgyz Republic, the list of regressors includes the gender, age, and education level of a household head, the number of dwelling rooms, access to LPG and natural gas, and the type of heating system installed in the premises of a household.

6. RESULTS

Tables B1.1–B1.3 of Appendix B report the marginal effects from multinomial logit regressions for each country separately. Results on the determinants of major cooking fuel and mixes of cooking fuels for India are presented in Tables B1.1a and B1.1b, for Kazakhstan in Table B1.2, and for the Kyrgyz Republic in Tables B1.3a and B1.3b.

Access to Cleaner Fuels

Though our sample of households is limited to those that have access to electricity, households still use solid fuels because electricity is more expensive than solid fuels. However, households with access to gas, in particular access to LPG in India, access to natural gas in Kazakhstan, and access to natural gas and LPG in the Kyrgyz Republic, are less likely to use solid fuels for cooking. Households switch from solid fuels if they have access not only to electricity but also to natural gas, due to its lower price. Hence policies promoting gas infrastructure development will likely reduce the consumption of solid fuels for cooking in India, Kazakhstan, and the Kyrgyz Republic.

Convenience/Multiuse: Same Heating Fuel

In cold countries such as Kazakhstan and the Kyrgyz Republic, the heating system installed at the premises of a household can determine the choice of cooking fuel. This is because the same stove could be used for cooking and heating in the winter time. Here, we test how a heating system installed at the premises of a household affects the choice of cooking fuel in Kazakhstan and the Kyrgyz Republic.

In rural areas of Kazakhstan, any heating system has a positive and significant effect on the use of solid fuels, though the probability of choosing a solid fuel stove is highest in settlements that use a coal-based individual oven for heating. The positive effect is less pronounced in urban areas, where the effect of heating systems on the likelihood of using a solid fuel stove is positive but not significant. The effect of heating systems on LPG use is diverse across regions and heating systems. The significant impact of the heating system on the choice of cooking fuel shows the importance of providing access to clean energy not only for cooking but also for heating in promoting the use of clean fuels for cooking in cold countries.

In the Kyrgyz Republic, the use of coal and wood for heating increases the probability of using the same dirty fuels for cooking in both urban and rural areas. Use of electricity for heating increases use of gas cylinder and electricity as the dominant fuel for cooking. Heating based on piped gas decreases the use of gas cylinder as a dominant fuel for cooking. The piped gas infrastructure in the Kyrgyz Republic is available mainly in the area of the capital city, demonstrating its presence and significance in urban areas. These findings suggest that access to clean energy types for heating promotes the use of clean energy for cooking because of convenience.

Economic Factors

Per capita expenditure, access to free fuel, and energy prices are included as economic factors that can affect the choice of cooking fuel. Our results show that households with higher expenditure per capita (in India and the Kyrgyz Republic) or larger dwelling unit area (in Kazakhstan) are less likely to use solid fuels for cooking and are more likely to use clean fuels (i.e., electricity and gas). These results are in line with other studies that find households that tend to switch to clean fuel sources as their incomes increase, supporting the energy ladder hypothesis (Alem et al. 2016; Jaime, Chávez, and Gómez 2020).

The availability of free fuels is associated with lower fuel expenditure. This may reflect the fact that poor households mainly rely on human resources to collect wood and dry leaves in mostly rural areas. The availability of the data allows us to compare India and Kazakhstan. In general, the availability of free fuel increases the probability of using all fuel types in rural and urban areas in India. In Kazakhstan, it increases the probability of choosing LPG in rural areas and solid fuel and mixed electricity and gas in urban areas, while it reduces the probability of choosing mixed electricity and gas in rural areas and natural gas in urban areas.

Our results show that energy prices have a significant impact on the choice of cooking fuel. Studying the impact of energy prices is important, as they could be used to promote clean fuels. The results on energy prices are not reported for India due to data limitations. Average regional energy prices are used as a measure of energy prices in Kazakhstan and the Kyrgyz Republic. Households located in regions with higher coal prices are more likely to use clean fuels: electricity in Kazakhstan, natural gas in rural Kazakhstan, and gas cylinder in the urban Kyrgyz Republic. Similarly, households in Kazakhstan and the Kyrgyz Republic located in regions with lower gas prices are more likely to consume clean fuels such as natural gas and are less likely to use solid fuel ovens. Interestingly, households living in regions with higher electricity prices are more likely to use electric stoves. However, they are less likely to use solid fuel stoves in the Kyrgyz Republic and rural Kazakhstan. That contradicts the general expectation that higher prices reduce consumption of a product. However, it should be mentioned that despite the positive impact of electricity prices on electric stove usage, electricity prices in the Kyrgyz Republic and Kazakhstan are regulated by the government. Also, built-in infrastructure and living conditions limit fuel substitution. In general, using average regional energy prices presents a limitation for this study, showing the impact of prices at the regional rather than at the household level.

Built Environment

In India, ownership of a house and whether a household is a regular salary earner have a positive and significant effect on the probability of choosing solid fuels and negative and significant effects on the probability of choosing cleaner types of fuel, such as kerosene. This may be because households that own a house have more independence in optimizing fuel consumption and sparse availability. For example, households in rural India, which are mainly involved in agriculture (both livestock and agriculture), live in their own house and use crop residues as fuel for cooking their food and boiling cereals for livestock. This type of setup mostly has a chulha (a stove made of clay) in the courtyard. Due to the socioeconomic disadvantages across Scheduled Castes and Scheduled Tribes, they mostly rely on using dirty fuels. The effects only differ in magnitude.

In Kazakhstan, households that reside in apartments are more likely to choose natural gas and are less likely to choose solid fuel and LPG, which are predominantly used by households who live in detached houses. In the Kyrgyz Republic, the number of dwelling rooms has a positive and significant effect on the use of coal and wood in both rural and urban areas, reducing the probability of choosing gas, LPG, and electricity in rural areas, though it has a positive and significant effect on the use of LPG in urban areas. That is likely to be because solid fuel is used for heating purposes: therefore, the greater the number of dwelling rooms in the unit, the higher the probability of using solid fuel for cooking as well.

Household Characteristics

The gender of the head of the household affects the choice of cooking fuel. Households with male household heads are more likely to use electricity and other clean fuels in India. In contrast, in the Kyrgyz Republic, households with male heads are more likely to use coal and wood and are less likely to use electricity in rural areas, while such households are more likely to use coal and LPG and less likely to use piped gas in urban areas. The pertinent literature attributes the difference between the decisions made in male- and female-headed households to the difference in preferences and opportunity cost of time. In general, female-headed households are likely to be prone to interventions related to better access to modern energy and are more likely to switch to clean energy relative to male-headed households (Karimu, Mensah, and Adu 2016; Rahut, Behera, and Ali 2016). Interestingly, the findings for the Kyrgyz Republic are consistent with other studies while the results for India are, surprisingly, at odds with the literature.

The age of the household head affects the choice of cooking fuel. Households with older household heads are more likely to use LPG for cooking. In the Kyrgyz Republic, such households are more likely to use coal and wood and less likely to choose LPG stoves. In urban areas, such households are more likely to use gas and less likely to use LPG.

The education of the household head is a strong determinant of fuel demand in India and the Kyrgyz Republic. Households with more educated household heads are less likely to use coal, wood, and kerosene as a dominant cooking fuel in India. Likewise, in the Kyrgyz Republic, such households are more likely to use clean fuel such as electricity in rural areas, and are less likely to use coal and wood in both rural and urban areas. Our results show that education can lead to fuel switching. This result is aligned with other studies that show that the probability of using cleaner fuel sources increases with education (Alem et al. 2016; Karimu, Mensah, and Adu 2016; Paudel, Khatri, and Pant 2018).

Household size affects the choice of cooking fuel. Larger households are more likely to use coal and wood in India and more likely to use cleaner fuels such as kerosene and electricity in urban areas. In Kazakhstan, larger households are more likely to use electricity in rural and urban areas and less likely to use LPG in rural areas and mixed types of fuel in urban areas. In the Kyrgyz Republic, larger households are less likely to use electricity in rural and urban areas and more likely to use mixed fuels in urban areas. The results for India and the Kyrgyz Republic are consistent with the literature that shows that household size has a negative effect on the consumption of clean fuels and a positive effect on the consumption of dirty fuels (Paudel, Khatri, and Pant 2018). That is typical for developing countries, as larger households require more cooking fuel; hence, to reduce costs, they use cheaper fuels such as coal and wood. This is in contrast to the findings for Kazakhstan, where we find opposite results, pointing at the positive effect of household size on the probability of choosing cleaner fuels.

7. CONCLUDING REMARKS

This study provides a comprehensive analysis of the role of infrastructures such as access to clean fuels (in India, Kazakhstan, the Kyrgyz Republic) and heating systems (in Kazakhstan, the Kyrgyz Republic) in the choice of dirty and clean cooking fuels. The study uses household survey data from India, Kazakhstan, and the Kyrgyz Republic over the periods 2011–2012, 2017, and 2016, respectively, and applies MLM to study the determinants of the choice of clean and dirty cooking fuels.

The empirical findings for all countries demonstrate that the fuel type used for cooking is conditioned by many factors. Limited gas pipeline networks and instability of the electricity supply may have an important impact on household preferences. Therefore, the development of infrastructure and increased affordability of cleaner types of fuel, as measured by access to natural gas or LPG in the sample countries, are important factors for the transition to clean energy. Also, we find that the choice of fuel for cooking depends on the heating system installed in the premises of the households in cold countries such as Kazakhstan and the Kyrgyz Republic. This suggests that the transition to clean fuels for cooking should unambiguously take into account the heating system used by a household. Economic factors play a substantial role: in particular, households with higher per capita expenditure and higher income are inclined to move from solid fuel to LPG, natural gas, and electricity. That confirms the energy ladder hypothesis that suggests that households move away from dirty fuels to cleaner fuels.

In cold climate countries such as Kazakhstan and the Kyrgyz Republic, the heating season lasts for more than six months in the year, with average winter temperatures of -8℃ to -10℃ in some regions. Heating comprises nearly 60% of the end-use energy demand of households in Kazakhstan (UNDP 2012a). Most of households' energy expenditure is related to heating fuel. In this regard, finding and purchasing enough fuel for heating is of greater concern for households than cooking fuel. Generally, households will tend to use one stove for multiple purposes (originally for heating). The top surface of the heating stove is generally used for heating water and cooking during the wintertime.

In the Voluntary National Review of the Republic of Kazakhstan (Ministry of National Economy of the Republic of Kazakhstan 2019), Kazakhstan reported a 100% electrification rate, and thus fulfillment of SDG7, to "ensure access to affordable, reliable, sustainable and modern energy for all". Despite 100% electrification, our study shows that households in Kazakhstan heavily rely on solid fuels, 30% of surveyed households using solid fuels mainly for heating purposes. Thus, the electrification rate indicator may not be sufficient to address complex challenges with ensuring affordable access to sustainable fuel. The SDG7 should not only take into account the electrification rate, but should include the share of households relying on clean fuels and fuel stacking.

Also, current government efforts to provide wider access to cleaner affordable fuels have to be sustained, possibly even accelerated and expanded to cover more areas. A gas pipeline network could be constructed in densely populated areas of Kazakhstan while ensuring LPG supply in remote and distant locations where a gas pipeline is not possible. Additionally, in the case of the Kyrgyz Republic, efforts should be focused on reducing electricity outages to restore trust in electricity as a reliable source of energy. Transition to cleaner fuels requires substantial investment, but the health benefits may outweigh the costs. The governments of Kazakhstan and the Kyrgyz Republic could consider programs to subsidize the cost of a gas connection or a gas boiler, particularly

for rural low-income households. In wealthier urban areas with significant air quality issues associated with solid fuel use, a gradual coal ban can be considered, with subsidy programs for low-income and vulnerable populations. Such programs are in place in India, and the experience could be integrated in Kazakhstan and the Kyrgyz Republic.

Our paper poses the need for further studies. Firstly, future studies could look at questions related to the energy ladder and fuel stacking in heating—in particular, whether households are stacking up or down the energy ladder, similar to Choumert-Nkolo, Combes Motel, and Le Roux (2019). As cooking and heating are largely related in Kazakhstan and the Kyrgyz Republic, such studies could further contribute to the discussion on energy transition and related policies. Secondly, raising awareness of health damage due to air pollution is crucial; hence future studies could uncover the effects of energy demand on the health of different groups of the population. Thirdly, transition to cleaner fuels empowers women as it reduces cooking time and has health benefits, and so understanding gendered issues of cooking and heating fuel choices will uncover the benefits of the transition to clean fuel. In general, gender-related studies are limited for the sample countries, and such studies will shed light on a host of issues pertinent to these countries.

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APPENDIX: SUMMARY STATISTICS

Table A1.1: Distribution of Households by Their Primary Source of Cooking, India

	Rural		Urban		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Coal, wood, crop residual	31,667	67.1	7,345	19.7	39,012	46.2
LPG	13,960	29.6	27,821	74.6	41,781	49.4
Kerosene	481	1.0	1,616	4.3	2097	2.5
Electricity and biogas	209	0.4	240	0.6	449	0.5
Others	901	1.9	283	0.8	1,184	1.4
Total	47,218		37,305		84,523	

Source: National Sample Survey Organization (68th round); authors' calculations.

Table A1.2: Distribution of Households by Their Source of Cooking, Kazakhstan

	Rural		Urban		Total	
Fuel type	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Solid fuel	910	9.56	393	2.93	1,303	5.69
LPG	3,016	31.7	2,585	19.29	5,601	24.45
Natural gas	1,752	18.41	4,388	32.75	6,140	26.8
Mixed electricity and gas	700	7.36	858	6.4	1,558	6.8
Electricity	3,136	32.96	5,174	38.62	8,310	36.27
Total	9,514	100	13,398	100	22,912	100

Source: Committee of Statistics of the Republic of Kazakhstan (2017); authors' calculations.

Table A1.3a: Distribution of Households by Their Primary Source of Cooking, the Kyrgyz Republic

	Rural		Urban		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Stove (coal and wood)	969	62.28	226	23.71	1,195	47.63
Gas pipe supply	7	0.45	385	40.4	392	15.62
LPG gas stove	139	8.93	124	13.01	263	10.48
Electric	441	28.34	218	22.88	659	26.27
Total	1,556	100	953	100	2,509	100

Source: International Data Service Center (2016); authors' calculations.

Table A1.3b: Distribution of Households by Their Primary Source of Cooking in the Kyrgyz Republic (Including Mixed Sources of Fuel)

	Rural		Urban		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Stove (coal and wood)	324	20.82	24	2.52	348	13.87
Gas pipe supply	7	0.45	385	40.4	392	15.62
LPG gas stove	139	8.93	124	13.01	263	10.48
Electric	441	28.34	218	22.88	659	26.27
Mixed fuel (coal and wood stove with electric stove)	645	41.45	202	21.2	847	33.76
Total	1,556	100	953	100	2,509	100

Source: International Data Service Center (2016); authors' calculations.

Table A2.1: Descriptive Statistics for India

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Log of MPCE on fuel	85,619	4.999597	0.534136	0.693147	8.747828
Log of MPCE	85,619	7.012084	1.056935	0.693147	12.41521
Education of the head of household					
Primary	85,619	0.121013	0.326144	0	1
Middle and secondary	85,619	0.414441	0.492628	0	1
Diploma and above	85,619	0.159112	0.365783	0	1
Age	85,619	47.11245	13.28923	15	105
Gender of the Head (male=1)	85,619	0.887023	0.316567	0	1
Household size	85,619	4.578084	2.206122	1	31
House ownership	85,619	0.843913	0.36294	0	1
Regular salary earner	85,609	0.3320525	0.470966	0	1
Social group (base category=Scheduled Caste)					
Scheduled Tribes	85,611	0.142622	0.349689	0	1
OBC	85,611	0.391492	0.488087	0	1
Others	85,611	0.337807	0.472965	0	1
Access to free fuel	85,619	0.378152	0.484929	0	1
Sector (rural=1)	85,619	1.44698	0.497184	1	2
Access to LPG	85,619	0.567491	0.495427	0	1

Table A2.2: Descriptive Statistics for Kazakhstan

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Total area, m2	20,993	69.18	51.48	9.00	1,000.00
Log of energy costs per capita (annual)	8,466	10.06	1.10	1.50	13.71
Access to natural gas (=1 if household has access to natural gas)	21,000	0.41	0.49	0	1
Free fuel (=1 if household has free fuel access)	21,000	0.04	0.20	0	1
Household size	21,000	3.28	1.88	1.00	15.00
Coal log price	21,000	9.42	0.22	8.97	9.74
Natural gas log price	12,602	3.19	0.49	2.08	3.56
Electricity log price	21,000	7.37	0.25	6.57	7.70
Urban (=1 if household resides in an urban area)	21,000	0.66	0.47	0	1
Apartment (=1 if household resides in apartment or dormitory)	21,000	0.59	0.49	0	1

Source: Committee of Statistics of the Republic of Kazakhstan (2017); authors' calculations.

Table A2.3: Descriptive Statistics for the Kyrgyz Republic

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Monthly per capita expenditure of household (Som)	2,521	3,933.65	2,587.57	7.00	29,923
Log of total expenditure of household on energy	2,458	5.05	0.76	1.51	7.41
Access to gas (=1 if household has access to LPG)	3,106	0.23	0.42	0	1
Age of household head	2,521	53.97	13.45	21.00	90.00
Gender of household head (=1 if male)	2,521	0.71	0.45	0.00	1.00
Household head education					
Secondary	2,169	0.52	0.50	0.00	1.00
Technical	2,169	0.17	0.37	0.00	1.00
Tertiary	2,169	0.17	0.37	0.00	1.00
Household size	2,521	5.26	2.54	1.00	17.00
Dwelling rooms	2,320	3.60	1.36	1.00	12.00
Rural	2,521	0.62	0.49	0.00	1.00

Source: International Data Service Center (2016); authors' calculations.

Table A3.1: Pairwise Combination of Fuel Demand in India
(number of households)

	Coal	LPG	Kerosene	Electricity	Wood
All India					
Coal	2,995				
LPG	988	48,588			
Kerosene	2,465	22,844	55,013		
Electricity	2,954	48,424	54,817	85,292	
Wood	1,574	17,076	40,576	48,948	49,124
Rural					
Coal	1,425				
LPG	415	19,377			
Kerosene	1,236	12,068	37,207		
Electricity	1,406	19,334	37,097	47,201	
Wood	1,009	12,335	32,365	38,380	38,513
Urban					
Coal	1,570				
LPG	573	29,211			
Kerosene	1,229	10,776	17,806		
Electricity	1,548	29,090	17,720	38,091	
Wood	565	4,741	8,211	10,568	10,611

Source: National Sample Survey Organization (68th round); authors' own calculations.

Table A3.2: Pairwise Combination of Fuel Demand for Cooking in Kazakhstan
(number of households)

	Solid Fuel	LPG	Mixed Electricity and Gas	Natural Gas	Electricity
All Kazakhstan					
Solid fuel	1,303				
LPG	933	5,601			
Mixed electricity and gas	135	140	1,558		
Natural gas	22	7	79	6,140	
Electricity	550	1,720	533	1,091	8,310
Rural households					
Solid fuel	910				
LPG	658	3,016			
Mixed electricity and gas	90	115	700		
Natural gas	22	5	43	1,752	
Electricity	412	1,131	375	540	3,136
Urban households					
Solid fuel	393				
LPG	275	2,585			
Mixed electricity and gas	45	25	858		
Natural gas	0	2	36	4,388	
Electricity	138	589	158	551	5,174

Source: Committee of Statistics of the Republic of Kazakhstan (2017); authors' calculations.

Table A.3.3: Pairwise combination of fuel demand in the Kyrgyz Republic
(number of households)

	Coal	LPG	Electricity
Total Sample			
Coal	1,866		
LPG	376	717	
Electricity	1,794	677	2,375
Rural			
Coal	1,390		
LPG	213	242	
Electricity	1,323	205	1,446
Urban			
Coal	476		
LPG	163	475	
Electricity	471	472	929

APPENDIX B: REGRESSION RESULTS

Table B1.1a: Determinants of Major Cooking Fuel Choice in India, Marginal Effects (multinomial logit)

	Rural			Urban		
Variables	**Coal, Wood, Crop Residual**	**Kerosene**	**Electricity and Others**	**Coal, Wood, Crop Residual**	**Kerosene**	**Electricity and Others**
Log of MPCE	–0.0291	–0.0430	0.148***	–0.257***	–0.190***	0.403***
	(0.0205)	(0.0654)	(0.0437)	(0.0331)	(0.0475)	(0.0560)
Education of the head of household (base category=below primary)						
Primary	–0.116*	–0.132	–0.146	0.00155	0.177	0.232
	(0.0595)	(0.165)	(0.110)	(0.0901)	(0.124)	(0.187)
Middle and secondary	–0.416***	–0.279**	–0.406***	–0.728***	–0.598***	–0.214
	(0.0452)	(0.128)	(0.0861)	(0.0746)	(0.103)	(0.146)
Diploma and above	–1.009***	–1.015***	–0.683***	–1.749***	–2.196***	–0.187
	(0.0684)	(0.220)	(0.151)	(0.123)	(0.199)	(0.184)
Age (years)	–0.00345**	–0.00483	–0.00664**	–0.00554**	–0.0106***	0.00478
	(0.00146)	(0.00425)	(0.00287)	(0.00241)	(0.00336)	(0.00432)
Gender of the head (male=1)	–0.00110	0.127	0.457***	–0.0459	0.0131	0.426**
	(0.0576)	(0.170)	(0.136)	(0.0851)	(0.123)	(0.196)
Household size	0.116***	–0.0517	0.0959***	0.168***	–0.0651***	–0.0119
	(0.00882)	(0.0338)	(0.0182)	(0.0130)	(0.0225)	(0.0277)
House ownership	1.082***	–1.451***	1.608***	0.776***	–0.754***	0.203
	(0.124)	(0.167)	(0.264)	(0.0874)	(0.103)	(0.131)
Regular salary earner	0.181***	–0.559***	0.511***	0.238***	–0.276***	–0.241**
	(0.0397)	(0.118)	(0.0981)	(0.0642)	(0.0881)	(0.111)
Social group (base category=Scheduled Caste)						
Scheduled Tribes	0.877***	0.829***	1.989***	0.495***	0.709***	0.0447
	(0.0789)	(0.199)	(0.168)	(0.141)	(0.189)	(0.242)
OBC	0.648***	0.723***	1.494***	0.689***	0.567***	0.0825
	(0.0646)	(0.167)	(0.156)	(0.120)	(0.171)	(0.210)
Others	0.909***	1.568***	2.806***	0.280**	0.667***	0.757***
	(0.0649)	(0.169)	(0.152)	(0.125)	(0.174)	(0.202)
Access to free fuel	1.541***	0.0746	0.305***	2.451***	0.798***	0.578***
	(0.0372)	(0.114)	(0.0717)	(0.0682)	(0.134)	(0.210)
Access to LPG	–8.003***	–9.580***	–8.687***	–7.991***	–9.217***	–8.216***
	(0.199)	(0.312)	(0.222)	(0.161)	(0.200)	(0.196)
Observations	47,343	47,343	47,343	38,258	38,258	38,258

Notes: LPG is a base category. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.

Table B1.1b: Determinants of Major Cooking Fuel Combinations Choice in India, Marginal Effects (multinomial logit)

	LPG + Coal	LPG+ Kerosene	LPG + Wood
Log of MPCE	–0.163**	–0.359***	–0.200***
	(0.0776)	(0.0141)	(0.0168)
Education of the head of household (base category=below primary)			
Primary	–0.548*	0.0165	–0.0857
	(0.304)	(0.0521)	(0.0572)
Middle and secondary	–0.389**	–0.0480	–0.443***
	(0.193)	(0.0380)	(0.0426)
Diploma and above	–0.949***	–0.310***	–0.939***
	(0.234)	(0.0442)	(0.0530)
Age	0.00468	0.000635	–2.76e-05
	(0.00562)	(0.00102)	(0.00125)
Gender of the head (male=1)	0.327	0.0833**	–0.0257
	(0.245)	(0.0415)	(0.0480)
Household size	0.160***	0.172***	0.197***
	(0.0339)	(0.00706)	(0.00811)
House ownership	0.457**	0.592***	0.838***
	(0.179)	(0.0321)	(0.0451)
Regular salary earner	–0.368***	0.151***	0.227***
	(0.141)	(0.0260)	(0.0320)
Social group (base category=Scheduled Caste)			
Scheduled Tribes	–1.359***	–0.179***	–0.388***
	(0.328)	(0.0578)	(0.0637)
OBC	–1.275***	–0.00359	–0.222***
	(0.231)	(0.0475)	(0.0516)
Others	–0.478**	–0.287***	–0.992***
	(0.193)	(0.0469)	(0.0526)
Access to free fuel	–1.494	0.0333	3.946***
	(1.006)	(0.0893)	(0.0627)
Urban (rural=1)	0.268*	0.525***	1.442***
	(0.161)	(0.0291)	(0.0317)
Observations	48,576	48,576	48,576

Notes: Use of LPG without combination with other fuel is the base category. Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table B1.2: Determinants of Major Cooking Fuel Choice in Kazakhstan, Marginal Effects (multinomial logit)

	Rural				
Variables	**Solid Fuel**	**LPG**	**Mixed**	**Natural Gas**	**Electricity**
Heating stove (base category=central heating)*					
Autonomous (gas, electricity)	0.000901*	0.101*	0.0123	–0.176***	0.0619
	(0.000533)	(0.0602)	(0.0105)	(0.0208)	(0.0587)
Autonomous (gas, coal)	0.200***	–0.00602	0.249***	–0.444***	0.000848
	(0.0496)	(0.0291)	(0.0659)	(0.0192)	(0.0445)
Oven (gas, electricity)	0.0107**	–0.0817	0.0312**	–0.133***	0.173***
	(0.00474)	(0.0576)	(0.0130)	(0.0232)	(0.0553)
Oven (coal, other)	0.188***	–0.0489	0.0416	–0.394***	0.214***
	(0.0429)	(0.0300)	(0.0411)	(0.0396)	(0.0521)
Oven (coal only)	0.272***	0.0593**	0.000631	–0.343***	0.0109
	(0.0439)	(0.0271)	(0.0190)	(0.0353)	(0.0386)
Access to natural gas	0.131***	–0.459***	0.0562**	0.296***	–0.0232
	(0.0309)	(0.0643)	(0.0231)	(0.0257)	(0.0527)
Access to free fuel	–0.000424	0.0365**	–0.0439**	0.0128	–0.00504
	(0.00879)	(0.0148)	(0.0203)	(0.0263)	(0.0239)
Household size	0.000387	–0.00631***	–0.00205	0.00146	0.00651**
	(0.00156)	(0.00241)	(0.00139)	(0.00212)	(0.00277)
Coal log price	0.0573	–1.062***	–0.214***	0.181***	1.038***
	(0.0526)	(0.0763)	(0.0426)	(0.0646)	(0.0908)
Natural gas log price	–0.0176	–0.000444	0.0808***	–0.0743***	0.0115
	(0.0126)	(0.0198)	(0.0152)	(0.0229)	(0.0276)
Electricity log price	–0.135***	–0.208***	–0.145***	0.00932	0.478***
	(0.0330)	(0.0471)	(0.0272)	(0.0464)	(0.0683)
Apartment	0.00690	–0.0495***	–0.0312***	0.0622***	0.0117
	(0.0104)	(0.0159)	(0.00910)	(0.0128)	(0.0184)
Total area, m2	–5.34e-05	4.26e-05	9.50e-05**	–8.12e-05	–2.95e-06
	(9.17e-05)	(0.000137)	(3.72e-05)	(7.52e-05)	(0.000142)
Observations	6,155	6,155	6,155	6,155	6,155

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Table B1.2 *continued*

	Urban				
Variables	**Solid Fuel**	**LPG**	**Mixed**	**Natural Gas**	**Electricity**
Heating stove (base category=central heating)*					
Autonomous (gas, electricity)	0.00122	–0.0619***	–0.00249	–0.0876***	0.151***
	(0.00143)	(0.0237)	(0.00953)	(0.0222)	(0.0259)
Autonomous (gas, coal)	0.0546	0.0860***	–0.0508***	–0.292***	0.203**
	(0.0523)	(0.0283)	(0.00460)	(0.0928)	(0.0848)
Oven (gas, electricity)	4.57e-10	–0.00879	0.0550***	–0.190***	0.144***
	(1.46e-06)	(0.0251)	(0.0163)	(0.0261)	(0.0309)
Oven (coal, other)	0.154	–0.0419***	–0.0508***	–0.602***	0.541***
	(0.106)	(0.0140)	(0.00460)	(0.0360)	(0.0981)
Oven (coal only)	0.227	0.0512***	–0.0161	–0.585***	0.322***
	(0.144)	(0.0177)	(0.0231)	(0.0329)	(0.112)
Access to natural gas	0.0301	–0.195***	0.0543***	0.268***	–0.158***
	(0.0228)	(0.0169)	(0.0164)	(0.0192)	(0.0193)
Access to free fuel	0.0235***	0.0163	0.0403*	–0.196***	0.115***
	(0.00361)	(0.0109)	(0.0221)	(0.0561)	(0.0439)
Household size	0.000452	–0.00149	–0.00348**	–0.00115	0.00566**
	(0.000869)	(0.00166)	(0.00159)	(0.00262)	(0.00262)
Coal log price	0.0282	–0.333***	–0.193***	–0.296***	0.794***
	(0.0360)	(0.0597)	(0.0492)	(0.0772)	(0.0843)
Natural gas log price	–0.0221**	0.0955***	0.198***	–0.163***	–0.109***
	(0.00914)	(0.0180)	(0.0209)	(0.0269)	(0.0262)
Electricity log price	–0.00870	–0.151***	–0.250***	–0.163***	0.573***
	(0.0237)	(0.0441)	(0.0373)	(0.0576)	(0.0627)
Apartment	0.0114***	–0.0291***	0.00917	–0.0707***	0.0793***
	(0.00414)	(0.00854)	(0.00882)	(0.0165)	(0.0157)
Total area, m2	5.31e-05	–0.000436***	4.18e-05	–7.79e-05	0.000419***
	(5.31e-05)	(0.000102)	(3.42e-05)	(6.35e-05)	(9.47e-05)
Observations	7,748	7,748	7,748	7,748	7,748

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table B1.3a: Determinants of Major Cooking Fuel Choice in the Kyrgyz Republic, Marginal Effects (multinomial logit)

	Urban			
	Oven (Coal and Wood)	**Gas Pipe**	**Gas Cylinder**	**Electric Stove**
MPCE	9.29e-06*	–4.60e-06	2.30e-07	–4.92e-06
	(5.29e-06)	(4.42e-06)	(3.84e-06)	(5.65e-06)
Gender of household head (=1 if male)	0.0367	–0.0656***	0.0191	0.00979
	(0.0247)	(0.0240)	(0.0223)	(0.0260)
Age	–0.000437	0.00215**	–0.00243***	0.000721
	(0.000920)	(0.000944)	(0.000855)	(0.00100)
Secondary	–0.00422	0.00548	0.0272	–0.0285
	(0.0377)	(0.0417)	(0.0360)	(0.0419)
Higher secondary (technical)	–0.0550	0.0570	0.0227	–0.0247
	(0.0418)	(0.0444)	(0.0374)	(0.0467)
Graduate and above	–0.0498	–0.00637	0.0261	0.0301
	(0.0446)	(0.0440)	(0.0373)	(0.0493)
Household size	0.0153***	0.00209	–0.00449	–0.0129*
	(0.00588)	(0.00625)	(0.00576)	(0.00729)
Electricity	–0.135***	–0.440***	0.200***	0.374***
	(0.0364)	(0.0534)	(0.0430)	(0.0456)
Stove (coal and wood)	0.127***	–0.472***	0.175***	0.170***
	(0.0378)	(0.0416)	(0.0270)	(0.0340)
Gas	–0.00849	0.0493	–0.0264***	–0.0144
	(0.119)	(0.111)	(0.00918)	(0.0787)
Electricity log price	–2.990***	0.183	0.662	2.145***
	(0.658)	(0.708)	(0.634)	(0.741)
Coal log price	0.840	0.303	1.343**	–2.486***
	(0.591)	(0.682)	(0.646)	(0.672)
Gas log price	0.529*	–0.353	0.0172	–0.193
	(0.318)	(0.428)	(0.334)	(0.373)
Access to gas	–0.0968***	0.223***	0.0864***	–0.212***
	(0.0243)	(0.0205)	(0.0187)	(0.0246)
Dwelling rooms	0.0200**	0.0207**	0.00659	–0.0472***
	(0.00837)	(0.00888)	(0.00739)	(0.0107)
Observations	812	812	812	812

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Table B1.3a *continued*

	Rural			
	Oven (Coal and Wood)	**Gas Pipe**	**Gas Cylinder**	**Electric Stove**
MPCE	–7.09e-07	–1.58e-06	4.84e-06*	–2.55e-06
	(6.96e-06)	(1.50e-06)	(2.66e-06)	(6.96e-06)
Gender of household head (=1 if male)	0.0357	0.000115	0.00418	–0.0400
	(0.0279)	(0.00386)	(0.0143)	(0.0286)
Age	–0.000185	0.000238	–0.000339	0.000286
	(0.000964)	(0.000164)	(0.000476)	(0.000991)
Secondary	–0.0961***	0.00316	0.0118	0.0811**
	(0.0313)	(0.00396)	(0.0144)	(0.0317)
Higher secondary (technical)	–0.0835**	–0.00194	–0.00457	0.0900**
	(0.0420)	(0.00209)	(0.0179)	(0.0429)
Graduate and above	–0.0591	0.0173	–0.0120	0.0537
	(0.0452)	(0.0169)	(0.0231)	(0.0462)
Household size	0.00704	–0.00112	0.00425	–0.0102*
	(0.00553)	(0.00109)	(0.00282)	(0.00575)
Electricity				
Stove (coal and wood)	0.127***	0.000361	–0.0691***	–0.0581
	(0.0469)	(0.00510)	(0.0123)	(0.0457)
Gas				
Electricity log price	–6.612***	–0.243	–0.621	7.477***
	(0.823)	(0.304)	(0.753)	(0.948)
Coal log price	1.681***	0.143	0.733	–2.557***
	(0.585)	(0.245)	(0.500)	(0.640)
Gas log price	2.149***	–0.0683	–1.387***	–0.693*
	(0.325)	(0.0757)	(0.250)	(0.355)
Access to gas	–0.188***	0.00514	0.0304**	0.152***
	(0.0327)	(0.00409)	(0.0120)	(0.0327)
Dwelling rooms	0.0131	–0.00501*	–0.000494	–0.00764
	(0.00982)	(0.00299)	(0.00478)	(0.00998)
Observations	1,304	1,304	1,304	1,304

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table B1.3b: Determinants of Major Cooking Fuel Choice including Mixed Fuel in the Kyrgyz Republic, Marginal Effects (multinomial logit)

	Urban				
Equation	**Oven (Coal and Wood)**	**Gas Pipe**	**Gas Cylinder**	**Electric Stove**	**Mixed Fuel**
MPCE	1.78e-08	–4.55e-06	2.20e-07	–5.04e-06	9.35e-06*
	(2.63e-06)	(4.42e-06)	(3.85e-06)	(5.66e-06)	(5.28e-06)
Gender of household head (=1 if male)	0.0235	–0.0657***	0.0188	0.00892	0.0146
	(0.0153)	(0.0240)	(0.0224)	(0.0260)	(0.0246)
Age	–0.000375	0.00215**	–0.00243***	0.000765	–0.000113
	(0.000458)	(0.000944)	(0.000855)	(0.00100)	(0.000899)
Secondary	0.00451	0.00516	0.0273	–0.0274	–0.00957
	(0.0188)	(0.0417)	(0.0360)	(0.0418)	(0.0356)
Higher secondary (technical)	–0.0125	0.0562	0.0225	–0.0248	–0.0415
	(0.0190)	(0.0444)	(0.0374)	(0.0465)	(0.0400)
Graduate and above	–0.00166	–0.00670	0.0258	0.0319	–0.0493
	(0.0217)	(0.0440)	(0.0373)	(0.0493)	(0.0432)
Household size	–0.00339	0.00249	–0.00445	–0.0126*	0.0180***
	(0.00336)	(0.00628)	(0.00578)	(0.00733)	(0.00569)
Electricity	–0.00821	–0.440***	0.201***	0.372***	–0.125***
	(0.0126)	(0.0533)	(0.0430)	(0.0457)	(0.0361)
Stove	0.0259*	–0.472***	0.175***	0.170***	0.101***
	(0.0154)	(0.0415)	(0.0270)	(0.0341)	(0.0371)
Gas	–0.0148	0.0481	–0.0263***	–0.0162	0.00924
	(0.0108)	(0.111)	(0.00916)	(0.0778)	(0.120)
Electricity log price	–0.197	0.173	0.645	2.152***	–2.773***
	(0.360)	(0.708)	(0.634)	(0.742)	(0.674)
Coal log price	0.188	0.297	1.351**	–2.497***	0.661
	(0.339)	(0.682)	(0.647)	(0.673)	(0.598)
Gas log price	–0.228	–0.368	0.00764	–0.209	0.798***
	(0.174)	(0.428)	(0.333)	(0.373)	(0.309)
Access to gas	–0.0144	0.222***	0.0865***	–0.213***	–0.0808***
	(0.0126)	(0.0205)	(0.0187)	(0.0247)	(0.0250)
Dwelling rooms	0.00280	0.0208**	0.00670	–0.0470***	0.0167**
	(0.00428)	(0.00888)	(0.00739)	(0.0107)	(0.00803)
Observations	812	812	812	812	812

continued on next page

Table B1.3b *continued*

	Rural				
Equation	**Oven (Coal and Wood)**	**Gas Pipe**	**Gas Cylinder**	**Electric Stove**	**Mixed Fuel**
MPCE	7.75e-06	–1.58e-06	4.83e-06*	–2.37e-06	–8.63e-06
	(7.24e-06)	(1.50e-06)	(2.66e-06)	(7.00e-06)	(8.63e-06)
Gender of household head (=1 if male)	0.0390	0.000165	0.00404	–0.0395	–0.00366
	(0.0281)	(0.00387)	(0.0143)	(0.0286)	(0.0315)
Age	–0.00154*	0.000237	–0.000346	0.000236	0.00142
	(0.000893)	(0.000163)	(0.000475)	(0.000990)	(0.00105)
Secondary	–0.159***	0.00313	0.0115	0.0778**	0.0663*
	(0.0351)	(0.00395)	(0.0145)	(0.0319)	(0.0368)
Higher secondary (technical)	–0.133***	–0.00193	–0.00489	0.0863**	0.0539
	(0.0453)	(0.00208)	(0.0180)	(0.0430)	(0.0489)
Graduate and above	–0.211***	0.0173	–0.0125	0.0508	0.155***
	(0.0442)	(0.0169)	(0.0231)	(0.0463)	(0.0518)
Household size	0.00351	–0.00113	0.00423	–0.0102*	0.00360
	(0.00525)	(0.00110)	(0.00282)	(0.00577)	(0.00616)
Electricity					
Stove	0.111	0.000288	–0.0695***	–0.0661	0.0240
	(0.0700)	(0.00511)	(0.0123)	(0.0468)	(0.0660)
Gas					
Electricity log price	–6.318***	–0.236	–0.486	8.276***	–1.236
	(1.399)	(0.308)	(0.752)	(0.999)	(1.146)
Coal log price	4.916***	0.138	0.610	–3.256***	–2.408***
	(1.154)	(0.249)	(0.499)	(0.702)	(0.882)
Gas log price	0.928**	–0.0693	–1.402***	–0.878**	1.421***
	(0.394)	(0.0760)	(0.250)	(0.361)	(0.433)
Access to gas	–0.131***	0.00512	0.0305**	0.152***	–0.0572
	(0.0437)	(0.00408)	(0.0120)	(0.0328)	(0.0454)
Dwelling rooms	–0.00886	–0.00498*	–0.000488	–0.00757	0.0219**
	(0.00975)	(0.00297)	(0.00478)	(0.00999)	(0.0109)
Observations	1,304	1,304	1,304	1,304	1,304

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.