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Transitions from dirty to clean energy in low-income countries: insights from Kyrgyzstan

Rahat Sabyrbekov [a,b] and Nurgul Ukueva[a]

[a]Department of Economics, American University of Central Asia, Bishkek, Kyrgyzstan; [b]School of Economics and Business, Norwegian University of Life Sciences, Aas, Norway

ABSTRACT
Air pollution from the burning of fossil fuels in developing counties is a global challenge due its climate change and health effects. Dirty fuel and air pollution have become a serious issue in many Central Asian countries. This article studies the factors that affect household decisions to transition from dirty energy to clean modern fuels using panel data from Kyrgyzstan. The article argues that the choice of fuel depends on a number of endogenous and exogenous factors. Contrary to the conventional wisdom of the 'energy ladder' hypothesis, high income does not lead to a full switch to modern fuel, but rather facilitates the transition to consumption of energy from multiple fuel sources. Factors that increase the chances of full fuel transition are education and access to gas. By contrast, the number of elderly family members and size of the house negatively affect the transition to clean energy use.

KEYWORDS
Fuel switch; energy; Kyrgyzstan; pollution

Introduction

Global economic growth has been accompanied by higher household energy consumption and has transformed the face of the planet through urbanization and the higher demand for services and goods (Antrop 2004; DeFries and Pandey 2010; Franco, Ravibabu, and Mohan 2016). Residential energy consumption accounts for 35% of global energy use, with households in developing countries using the energy primarily for cooking, heating and cooling (Daioglou, van Ruijven, and van Vuuren 2012).

Higher energy consumption and its corresponding growing carbon footprint are emerging research topics (e.g. Sommer and Kratena 2016), and these topics will probably dominate the energy agenda in developed and developing countries in light of intensifying climate change. In the case of developing countries, issues of environmental degradation and energy demand pose a high concern for policymakers who must work within tight financial constraints to address the externalities (Alam, Fatima, and Butt 2007; Adkins, Oppelstrup, and Modi 2012). Greenhouse gas emissions in the residential sector have increased in developing countries, and are having a significant impact on worldwide air pollution (Nejat et al. 2015).

Based on the level of pollution produced, energy sources for residential consumption are divided into polluting (dirty) and modern (clean, less polluting). Biomass, wood and

CONTACT Rahat Sabyrbekov rahat.sabyrbekov@nmbu.no

coal are considered more polluting than gas and electricity; and use of the former fuels is dominant in developing countries. At the country level, this tendency in fuel choice contributes to global climate change and intensifies change in local natural ecosystems. At a household level, the use of polluting fuels worsens indoor air quality and negatively affects occupants' health (Kolokotsa and Santamouris 2015).

A transition from dirty to modern fuel is desirable, but it poses a number of new challenges. Macroeconomic and, indeed, global energy consumption patterns are dependent on complex decision-making processes within the household that ultimately define direct and indirect energy use. The growing body of literature on factors that influence the transition to modern fuels is important for the development of evidence-based policy. Different models have been developed, and empirical work has been done. However, the only agreement on household energy behaviour is that it is influenced by a variety of endogenous and exogenous factors (e.g. Jones, Fuertes, and Lomas 2015) (this is discussed further in the Conceptual Framework section). Despite the growing interest, the elements of the energy transitions remain unclear.

As in many developing countries, the Central Asian governments have asserted a strong commitment to reducing emissions and to moving along a 'green' and sustainable development path. However, the countries continue to experience growing CO_2 emissions and are challenged by a lack of effective energy policy and outdated Soviet infrastructure (Karakaya and Özçağ 2005; Akhmetov 2015). Of the 12 Central Asian cities studied, only four were under the limit for NO_2 concentration. Central Asian cities have lately became notorious for their air pollution due to dirty heating methods (Bloomberg 2016; 24.kg 2017), primarily the burning of coal by private households.

This study attempts to define the factors that influence household decisions to abandon traditional fuels and to adopt modern fuels for space heating in a low-income country. To our knowledge, the paper by Gassmann and Tsukada (2014) is the only study which researched factors of fuel switching in Kyrgyzstan. The authors used one year of household data in a quantitative approach. Following Gassmann and Tsukada we use 'fuel switching' to study the likelihood of use of particular type of fuel for heating. The contribution of our study is twofold. First, we use a much larger data set, taken from four years of household data. Second, our method includes qualitative components through the use of interviews with and direct questioning of respondents to identify factors that are not captured by a purely quantitative model. To our knowledge, no other study of household-level decisions to switch to modern fuels in Central Asia has used a combination of panel data and a qualitative interview approach. Therefore, we believe that this study will fill an important gap in the literature and assist in policy development in the energy sector. The article uses both quantitative and qualitative approaches to study the energy transition in a low-income country, and the findings are relevant to developing countries.

The article first outlines the main theoretical concepts in fuel transition studies and describes the current context of energy consumption in Kyrgyzstan. The data structure, main variables and empirical model are then described. Finally, the results, conclusions and implications of the study are discussed.

Transition to clean energy: conceptual framework

Three main theoretical models have ben used to explain the transition to cleaner energy on a household level: the energy ladder hypothesis, fuel stacking theory and the energy services concept. The models vary in their explanations of household decision-making and the importance of the affecting factors.

The energy ladder hypothesis states that as income rises, a household moves toward less polluting modern energy sources. The theory also predicts greater technological sophistication as energy sources change (Van Der Kroon, Brouwer, and Van Beukering 2013). This implies that a growth of income would enable a household to choose electricity over coal. The energy ladder hypothesis seems to have been confirmed by a great deal of empirical work (see the review by Rahut, Behera, and Ali 2017).

Critics of the theory argue that fuel transition is not linear, and households tend to 'stack' multiple fuels rather than shifting completely (Masera, Saatkamp, and Kammen 2000; Baiyegunhi and Hassan 2014; Ogwumike, Ozughalu, and Abiona 2014). Fuel stacking theory argues that a household has an array of energy sources and uses a combination of fuels, depending on availability and preference. Fuel stacking theory offers a more complex view of the decision-making process in households. This model was extended by Masera, Saatkamp, and Kammen (2000), who developed the 'multiple fuel model' to include both urban- and agricultural-household decision-making models, showing that access to energy sources is one of the key determinants of the energy mix used (Alam, Fatima, and Butt 2007). This has led to the development of even more elaborate models, and has been backed by growing empirical evidence (Kroon, Brouwer, and Beukering 2013).

Sovacool (2011) proposed another approach to look at household energy consumption, the energy services concept. Energy is used to provide a number of direct and indirect services. Direct services include activities such as cooking, space heating, lighting, water heating, and washing, while the indirect services include the energy embodied in goods and services, such as shoes or food products. The energy services approach allows researchers to widen the policy scope and to concentrate on an end-use agenda, rather than one purely focussed on energy supply and direct consumption.

Overall, household energy consumption has proven to be a complex research topic, and has thus far produced no consensus on clean energy transition. Energy consumption is affected by the usual suspects such as income and education, but also by less predictable factors such as culture and traditions (Zhang and Hassen 2017). For instance, cooking habits are hard to change, even if modern fuel is available (Masera, Saatkamp, and Kammen 2000; Baiyegunhi and Hassan 2014). Globalization may also impact energy consumption patterns through the flow of ideas, images, people and remittances (Sahakian 2011). Jones, Fuertes, and Lomas (2015) found 62 factors that influence electricity consumption in the residential sector. Stephenson et al. (2015) found that individual, household and business culture all affect energy use patterns. To make things even more complex, energy consumption levels can also be altered through public information programmes (Reiss and White 2008).

As policy development is made difficult by the multidimensional nature of the household decision-making process on energy consumption, Lopes, Antunes, and Martins (2015) have called for a comprehensive approach that includes a variety of soft and hard policy measures. Kowsari and Zerriffi (2011) also underline the need to capture endogenous and exogenous factors in policy development.

Context: brief overview of the energy sector and its challenges

Crumbling energy supply sector and growing residential consumption

According to Kyrgyz national development documents, the energy sector is a strategic sector highlighted for its importance to the well-being of the population and industry (GovKR 2012). For the last few years, the Kyrgyz government has been pondering an unpopular increase of tariffs for electricity while fully acknowledging the possible negative impact of previous such decisions (Wooden 2014). The question of the electricity tariff increase is discussed every year in Kyrgyzstan.

Hydropower is the main energy source, accounting for 93% of the total electricity of Kyrgyzstan. The other 7% is generated at thermal power stations. The country has a large hydropower potential, with a capacity of 142.5 billion kWh or 142,500 GWh in its 252 rivers, of which 3% is currently used. Of the nine government-owned power stations, seven are hydropower stations, with Toktogul claiming the highest generating capacity, at 1200 MWh. The two thermal power stations, one in Bishkek and one in Osh, are mainly used for residential heating. There are also 11 small private hydropower stations. The construction of a new thermal plant at Kara Keche is in progress.

The overall institutional structure is influenced by the region's Soviet heritage, designed to secure energy exchange between Central Asian countries. The break-up of the Union caused many challenges for the Kyrgyz energy industry. Recent attempts to reduce dependency on a shared international network have included the construction of new high-voltage power plants.

Soviet infrastructure was designed to satisfy the dominant industry, with the expectation that residential energy consumption was small. Since the break-up of the Soviet Union, the structure of energy consumption has changed. Residential consumption has risen to 65%, while industry consumption has fallen to 12%; services are at 12%, the public sector 10%, and agriculture 1%. On average, annual energy consumption by households has increased by 3–5% (GovKR 2008).

The national energy sector development strategy emphasizes four policy priorities: improving the state system for regulation and incentivizing of energy saving; empowering local administration and public organizations in energy saving and energy efficiency; facilitating an environment for the implementation of energy-efficient technologies for buildings; and implementing renewable energy sources. Recently, Kyrgyzstan joined the Regulatory Indicators for Sustainable Energy (RISE), a World Bank–supported initiative. RISE supports policymaking and identification of the benchmarks for sector policy and regulatory frameworks against those of regional and global peers. The RISE indicators may help improve the country's energy sustainability. At the moment, it is too early to know. Within the initiative framework, the government has claimed to include energy sustainability in all development programmes at every level. The government has also promised to create a system of economic incentives to reduce energy-use intensity (World Bank 2015). The latest country development strategies also see expanding the green economy and reducing environmental pollution as priorities (GovKR 2018).

The country's energy sector faces a number of challenges. First, the outdated infrastructure and heavily subsidized electricity prices have made the sustainability of the energy supply weak due to the state budget deficit and a lack of investment in renewal projects

(Gassmann and Tsukada 2014). This vulnerability is compounded by the seasonality of Kyrgyzstan, with the demand for energy three times as high in winter as in summer. The government has implemented a number of measures to overcome this shortage.

Corruption and losses are the second-biggest challenge in the sector. The widespread electricity shortages and restrictions in 2008–2010 resulted in widespread public frustration, which led to the overthrow of the government in 2010 (Wooden 2014). Not surprisingly, the government sees coal and gas as substitutes for the crumbling electricity industry and has put effort into improving access to them. As a result, the coal mining industry has been growing, and new plans for thermal plants are being considered. The government also plans to dramatically extend gas access to 60% of the population, expanding beyond the cities where it currently exists to the remote mountain areas (Gazprom 2015).

Coal: rapidly growing mining and consumption

The usable contents of the explored coal reserves in Kyrgyzstan amount to 1.3 billion tons. Most of the coal mines were started in the 1960s and 1970s and have never had a significant technology update, so the industry has experienced a depreciation of fixed assets of up to 95%. The high transportation costs, non-transparent governance and outdated mining technologies make coal mining a very inefficient sector with high environmental impacts. Despite these high costs, the production of coal has been sharply increasing since 2010 (Figure 1).

In 2015, 54% of coal use was classified as for 'heating and energy generation' by the National Statistics Committee (Figure 2); the actual number could be even higher. This is because the official statistics do not clarify how the coal was used in 'trade and car repair'; thus, it remains unclear whether some of the coal in this category was used for heating or energy generation. Much of the coal used for heating in the residential sector is used in brick and adobe furnaces with very low energy efficiency (Balabanyan et al. 2015); see Figure 2.

Panel data description

This study uses four waves of Kyrgyz Integrated Household Survey (KIHS) data collected by the National Statistical Committee of Kyrgyzstan in 2008–2011. The KIHS is the largest

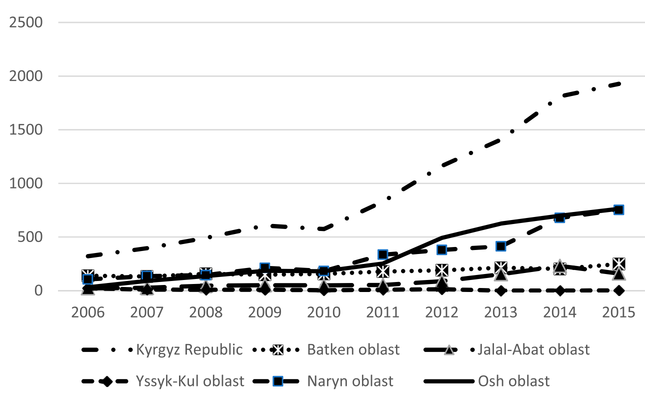

Figure 1. Coal production in Kyrgyzstan and across oblasts (in thousand tonnes). Source: National Statistics Committee.

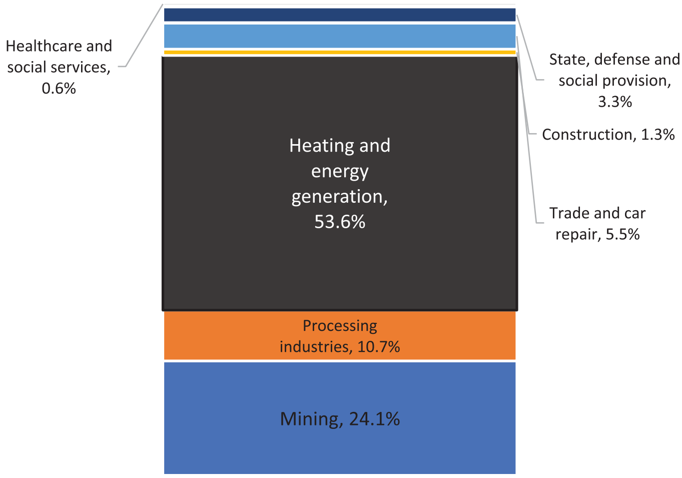

Figure 2. Coal consumption by sector (in thousand tonnes). Source: National Statistics Committee, 2015.

source of panel data in the country, containing information from approximately 5000 households each year on a wide range of topics, including income, expenditure, housing conditions, health, education and demographic characteristics. The survey is designed to be representative at the national, urban/rural, and regional (oblast) levels. KIHS is the only official state-funded household data that is used by the Kyrgyz government for policy analysis and development.

Developers of alternative, smaller sets of Kyrgyz panel data argue that KIHS has two drawbacks. First, the survey does not track household movement within Kyrgyzstan, and second, it is unclear how many households were excluded and whether this was because they migrated to another place or because of planned rotation (Esenaliev, Kroeger, and Steiner 2011). While these criticisms may be valid, for the objectives of this particular survey the KIHS data set remains the most applicable due to the extent of coverage, the great number of KIHS-based publications and its official government-approved status. Moreover, as the focus of this article is on national policy measures, we are not troubled by the question of oblast-level representativeness.

The sample for the KIHS is drawn from the 1999 population census using stratified two-stage random sampling. The KIHS is a rotating panel survey with about a 20% replacement rate. For this study, we used an unbalanced panel of 19969 observations, extending over four years in total.

Energy-related questions appear in two parts of the KIHS: the housing section and the expenditure section. In the housing section, among other questions related to housing types, amenities and networks of services such as water supply, garbage collection and sanitation, respondents are asked about the different sources of energy they use for heating and cooking. All sources of energy used for heating and cooking are listed; thus, an analysis of combinations of sources is possible.

In the expenditure section, questions are asked on household consumption of different types of energy, including firewood, coal, kerosene, pressed animal dung and others, as well as electricity and gas (in a different subsection). Information on the quantity consumed, as well as monetary amounts spent by fuel type, is also thus available.

Heating sources

In terms of sources of energy for heating, residential buildings can be of two types: connected to district heating systems or with individual heating sources. Multi-apartment buildings in Bishkek and other cities are mainly connected to district heating systems. About 17% of the households in the KIHS survey are. These households have no choice but to use district heating as their primary source of heating; but they might supplement it with other sources of energy.

Households in rural areas and individual houses in cities have their own individual heating sources. They use solid fuel-fired stoves (mainly coal), electricity or gas for heating. Many households use a combination of these sources. On average, over the four-year survey period, about 70% of households used a stove for heating, either alone or in combination with other sources of energy (electricity and gas), 33% used electricity, 17% used central heating, and 6% used gas (again either alone or in combination). These numbers illustrate only whether households ever used these sources of fuel; they do not indicate whether the given source is the only one or is used in combination with other sources as a primary or a secondary source.

About 25% of households reported having access to a gas supply. All households in Kyrgyzstan have access to electricity (100% in the survey). However, due to the poor condition of the aging power infrastructure and low hydropower output during winter, power outages are common, especially in winter (World Bank 2019). About 65% of surveyed households reported experiencing blackouts several times a year, and 16% at least once a month.

For the purposes of our research, we followed conventions established in previous relevant research (Heltberg 2004; Gassmann and Tsukada 2014) and specify the following three mutually exclusive categories for the dependent variable (details in the section on Methods):

- No switching – households use only solid fuel ('stove heating', in our survey's terminology)
- Partial switching – households use both solid fuel and electricity and/or gas
- Full switching – households use only modern fuel, i.e., only electricity and/or gas.

We excluded from our sample households with access to district heating systems, since those households have no choice but to use central heating.

Table 1 provides frequencies of the dependent variable over time for all households, and separately for urban and rural households. On average, over the period under consideration, about 58% of households used only solid fuel, 15% used only modern sources of energy and 27% combined modern and solid fuel sources.

Two major observations can be made from the table. First, there are large urban–rural differences in energy source use. Rural households are much more likely to use only traditional stoves for heating (76% of rural households versus 43% of urban households). Only about 2% of rural households have fully switched, whereas 26% of urban households have. Second, households in both urban and rural areas have been switching away from using only solid fuel. The percentage of households using only solid fuel sources fell from 62% in 2008 to 52% in 2011. However, these have only partially switched, with the number using a combination of fuel sources increasing over time. The percentage of

Table 1. Fuel mix use (in %) from the overall sample from the Kyrgyz Integrated Household Survey (2008–2011).

	All periods	2008	2009	2010	2011
		All households			
No switching	58.46	62.43	62.66	56.25	52.54
Partial switching	26.6	21.72	21.46	31.1	32.1
Full switching	14.94	15.85	15.87	12.65	15.36
Sample size	16,220	4,038	4,063	4,023	4,096
Urban households					
No switching	43.01	46.25	46.87	41.71	37.36
Partial switching	31.05	26.36	26.05	35.95	35.76
Full switching	25.94	27.39	27.08	22.34	26.89
Sample size	8,563	2,121	2,138	2,117	2,187
Rural households					
No switching	75.74	80.33	80.21	72.43	69.93
Partial switching	21.63	16.59	16.36	25.74	27.92
Full switching	2.63	3.08	3.43	1.84	2.15
Sample size	7,655	1,917	1,925	1,904	1,909

households that have fully switched has been stable at about 15%, while the percentage of households which have made a partial switch increased from 21% to 32%. Multiple cooking fuel use patterns have been reported frequently in the literature on household energy use. In Kyrgyzstan, households rely on multiple cooking fuels as a coping mechanism against blackouts and poor electricity supply, and against increases in the relative prices of modern fuel.

Methods

Econometric method

The literature suggests two methods for analysis: multinomial probit and multinomial logit. The multinomial probit model is used for estimation. The alternative method, multinomial logit, is commonly used to assess how exogenous variables affect the choice between several different discretionary outcomes, due to its computational simplicity. An important assumption of multinomial logit regression is the independence of irrelevant alternatives. This requires that adding another alternative or changing the characteristics of a third alternative does not affect the relative odds between alternatives. This is an important restriction in our model. To check the robustness of the results of our multinomial logit regression we use multinomial probit regression, which does not rely on the independence of irrelevant alternatives.

We ran our model using partial switching (i.e. using a combination of modern and traditional fuel) as the baseline category for the dependent variable. The results are interpreted relative to this baseline category. Thus, we can compare which factors are associated with the choice of modern fuel only, or traditional fuel only, as alternatives to using a combination of modern and traditional fuel.

Explanatory variables were chosen based on the literature. They included (1) a household's socio-economic characteristics – annual income per capita (adjusted for inflation using the natural logarithm), household size, head's age and gender, whether the head had higher education, and the proportion of elderly members; (2) housing and access to infrastructure – size of the dwelling in square metres, household's access to gas, and urban versus rural location; (3) energy prices – prices of electricity (som/kWh), gas (som/m^3), and coal (som/t); and (4) time and regional fixed effects.

Qualitative approach: interviews

To increase the rigour of the quantitative model, we also used a qualitative approach. In addition to the estimation of multinomial probit, we used in-depth interviews to gain deeper knowledge. The advantage of the interviews is that we could explicitly ask respondents about the reasons for their energy-source choices and their opinions on air pollution from use of solid fuels.

We interviewed 19 respondents from different areas and asked questions related to their energy-source preferences for heating. The respondent sample was randomly selected from an existing database established during previous research in urban and rural areas. We used convenience sampling, followed by the snowball method (Padgett 2017). We stopped conducting interviews once information saturation was reached (Jansen 2010).

The interview questions were about socio-demographic data, fuel choice, cost of heating, dwelling insulation and opinions on air pollution and its impacts (details in the Appendix). The interviews were conducted via telephone, and the respondents were informed that any information obtained would be confidential and anonymous.

Results

Results of the econometric model

Table 2 reports our analysis results for the whole country (for urban and rural subsamples, see Tables 5A and 6A in the Appendix). The tables present relative risk ratios, with standard errors in parentheses. Results should be interpreted only relative to the base choice, which is partial switching. Therefore, the parameters in the No Switching columns (Columns 1 and 3) show how exogenous variables affect the probability of households using only solid fuels for heating relative to using both solid and modern fuels. Similarly, the parameters in the Full Switching columns (Columns 2 and 4) show how exogenous variables affect the probability of choosing only modern fuel relative to choosing both modern and solid fuels. In these tables the coefficients should be compared to 1. Ratios greater than 1 indicate higher chances of choosing No Switching (for columns 1 and 3), or Full Switching (for columns 2 and 4), over Partial Switching (the reference category), while ratios less than 1 indicate lower chances.

The results show that income is associated with fuel switching for heating. The relative risk ratio for income is lower than the one for using only solid fuel and greater than one for using only modern fuel. This indicates that the higher the income, the more likely the households are to use a combination of modern and traditional fuel rather than only traditional fuels. It also indicates that the higher the income, the more likely that households will fully switch from a combination to the full use of modern fuel. However, it is only statistically significant at 'the first step' for switching from only solid fuel to the combination of both solid and modern fuels. A 1% increase in income increases the relative probability of using the combination rather than solid fuel only by 25 percentage points for the probit model. The effect of income is not statistically significant at the 'next step', that is, going from using the combination to full switching. Factors other than income, such as education, age, marital status of the household head, household size, and the size of the house seem to matter more for this 'second switching'. Coefficients on all these variables are statistically significant at this second stage.

Table 2. Estimation results, relative risk ratios, full sample.

	Multinomial probit	
VARIABLES	No switching	Full switching
Log of Income	0.746***	1.028
	(0.018)	(0.038)
Household size	0.954***	0.926***
	(0.010)	(0.015)
Head's age	0.998	0.991***
	(0.002)	(0.002)
Head with higher education	0.774***	1.296***
	(0.036)	(0.073)
Head female	0.944	0.926
	(0.053)	(0.067)
Head married	0.916	0.704***
	(0.053)	(0.052)
Number of elderly members	1.072*	0.829***
	(0.044)	(0.048)
Dwelling size	1.000	0.977***
	(0.001)	(0.001)
Have access to gas	0.355***	3.505***
	(0.020)	(0.204)
Coal price	0.999***	0.999***
	(0.000)	(0.000)
Electricity price	1.327	0.414***
	(0.311)	(0.134)
Issyk-Kul	0.833**	0.624***
	(0.071)	(0.061)
Djalal-Abad	0.505***	0.829**
	(0.042)	(0.072)
Naryn	0.551***	0.570***
	(0.048)	(0.058)
Batken	1.196**	0.982
	(0.106)	(0.097)
Osh	0.763***	0.727***
	(0.065)	(0.065)
Talas	0.327***	0.465***
	(0.028)	(0.047)
Chuy	1.032	0.577***
	(0.091)	(0.058)
Rural	1.717***	0.585***
	(0.064)	(0.034)
Dummy 2009	1.588***	1.428***
	(0.070)	(0.083)
Constant	3,414.973***	202.001***
	(1,633.367)	(130.813)
Observations	15,989	15,989

Notes: *p < 0.10, ** p < 0.05, *** p < 0.01.

Household-head education is another variable associated with fuel switching. The effect of education is statistically significant (at 1% significance) and large in magnitude at both stages. Compared to using the combination, the relative probability of using only solid fuel is 22 percentage points lower, and fully switching is 30 percentage points higher, for households with heads having higher education.

Living in areas with access to gas is the third variable associated with switching. Like education, it is associated with lower probability of using only solid fuel and higher probability of using only modern fuel. The effect is significant at both stages.

Having more elderly members appears to be negatively associated with fuel switching. It is associated with higher probability of using only solid fuel and lower probability of using only modern fuel relative to the base choice of using a combination of both. The relative probability of full switching is lower in households with an older head of household.

Households with large houses prefer to use a combination of both solid and modern fuels over using only modern fuel. A one-square-metre increase in house size reduces the probability of full switching by about 2 percentage points.

The price of electricity is also an important determinant in the use of modern types of fuel for heating. As expected, the higher the electricity price, the more likely that households use only solid fuel and do not partially replace stove heating with electricity. Also, at the second stage, the higher the electricity price, the more likely households are rely on a combination of energy sources rather than using only modern sources.

Living in rural areas tends to be negatively associated with fuel switching. It seems to increase the probability of using only solid fuel, and to reduce the probability of using only modern fuel, relative to the base choice of using of the combination of both.

Results from interviews

The sample (see Table 5) included respondents from five oblasts, with 53% living in rural areas. The mean self-reported wealth rank was 3, and the mean household size (number of people) was 5.2, with an average living area of 126 square metres. In the interviews, respondents noted that the living area was not necessarily equal to the heating area, because in winter many households use only one or two rooms. The minimum heating cost was 4000 som, with a maximum of 23,000 and a mean of 10,574 (Table 3).

Fuel use

The majority (84%) of respondents interviewed saw solid fuels as the main energy source for heating (Table 6). Solid fuels included coal, dung and wood. In the southern areas (Osh, Batken) the respondents mainly relied on wood due to its availability and the high price of coal, whereas in the north (Naryn) dung was more commonly used. One household in Naryn oblast used only dung due to its relative abundance and their low income.

Most of the households (60%) used solid fuels plus electricity. Some 57% of respondents insulated their houses. Insulation was done in floors, ceilings and walls. However, none of the respondents invested in energy-efficient windows; they expressed the view that any PVC (plastic) window would suffice. Interestingly, two respondents stated that they and neighbours had started insulating houses after a neighbour's house was insulated through an international donor project, and that this triggered a cascade of insulation across the village (Table 4).

Table 3. Socio-demographic information of the interviewed households.

Variable	Mean	Minimum	Maximum
Self-reported wealth status, from 1 (poor) to 5 (wealthy)	3	2	4
Number of people in the household	5.2	2	7
Age of the respondent	44	32	70
Number of people older than 55 years	1	0	2
Area of the house (in square metres)	126	60	330
Monthly cost of heating (in KGS)	10,574	4,000	23,000

Table 4. Use of fuel for heating and air pollution concerns (in percent).

Use solid fuel as primary energy source for heating	84.2%
Combine electricity and solid fuels	60%
Insulated house (walls, ceiling, windows, roof or floor)	57%
Acknowledge and are concerned with the health effects of use of solid fuels	58%

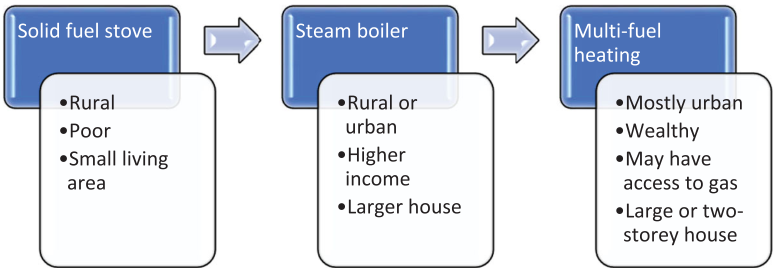

Figure 3. Transition scheme of heating systems and related household features. Source: authors' own.

Air pollution and its health effects

Most of the respondents interviewed (58%) were concerned with the harm to their health from solid fuel burning. In urban areas, the concern was mostly about pollution from neighbourhood use, while in rural areas the respondents were concerned with harm from their own use. One of the respondents stated that the use of dung for heating was a thousand-year-old tradition and had not observed any harm, unlike coal.

Reasons to use or not to use only electricity for heating

Only three households (one in Karakol and two in Bishkek) used only electricity for heating. The respondents in Karakol explained that their decision was due to the high energy efficiency of their houses and their concern with air pollution. The household in Bishkek identified the lack of a person to tend to the fire during the day as the primary reason for their use of electricity only. All three stated that their heating systems were also designed for use with coal in case of a blackout (Figure 3).

Among the solid fuel users, the most popular response (70% of all respondents) regarding the reason for not using only electricity was that the tariffs were too high. The second-most popular answer (15%) was that the voltage was low for heating purposes. Other respondents (14%) stated that they could not afford the cost of transitioning to electric heating, which would require installation of steam boiler, pipes and other related expenses. This was also true for some rural households (20%), where the pensions of retired household members were the only cash income for the household. Urban households with two-storey houses had multi-fuel heating systems that could use solid fuels, electricity and gas (Figure 4). Many respondents (80% of the subsample without gas access) were also confident that they would switch to gas from coal once the infrastructure is built.

Conclusion

Growing air pollution from the consumption of solid fuels has become a large concern for policymakers in many developing countries, including Central Asian states. Use of coal and biomass as fuel has harmful impacts on the health of the region. While many realize this threat, switching to cleaner fuels is challenging. Despite the growing recognition of the problem and work by international donors, there are surprisingly few studies that address the question of clean energy transition in the region.

This study looked into the factors that facilitate the switch from traditional polluting fuels to clean modern ones for residential heating in Kyrgyzstan. We used quantitative modelling and qualitative interviews. The quantitative model used data from four waves of KIHS structured interviews (2008–2011) providing detailed information on living conditions and energy consumption to construct a limited dependent variable model. The article builds upon and extends the work by Gassmann and Tsukada (2014) to identify the factors in the transition to clean fuel use.

Our key finding is that income growth alone does not lead to a full transition. Hence, with increasing incomes, air pollution will continue to grow unless new policies are introduced. Kyrgyz households do not transit to modern fuels in accordance with the predictions of the energy ladder hypothesis, suggesting that the Kyrgyz case is more in line with the multiple fuel model. Households with larger houses also tend to rely on a mixed-fuel strategy. This is may be because larger houses typically have more advanced heating systems that are designed to use multiple fuels. Indeed, the interviews showed that the poorest families rely on coal stoves, wealthier households use steam boilers (coal and electricity), and the wealthiest install multiple-fuel heating systems (Figure 4).

As in Gassmann and Tsukada (2014), our econometric model also showed that the price of fuel is an important criterion for fuel switching. This finding once again contributes to the ongoing debate on raising electricity tariffs. Proponents of the increase argue that it is a necessary step for the sustainability of the energy sector. On the other hand, the higher prices will lead to even more solid fuel use and, hence, air pollution. While our interviews do indicate that households have different availability of fuel sources and that some households, which produce large quantities of biomass or wood, are not likely to be affected by changes in market prices, biomass and wood are only efficient in small houses, and as living area increases, even for those with access to such sources, the likelihood of coal use grows.

Our quantitative model further found that the presence of a higher number of elderly household members is associated with the continuing use of dirty fuels. This result is more complex to explain, and further investigation is needed. However, in our view, one possible explanation could be the lower costs of coal and the fact that retired people have free time during the day to tend the fire. Another explanation could be that older people prefer traditional ways to heat the house and thus influence the household decision in that direction. In interviews, some respondents also stated that when retired members' pensions were the only source of income, the household did not have enough money to upgrade the heating system and so relied on solid fuels. The explanation can thus be related to time and income availability.

Households in rural areas also seem to be reluctant to switch fully to clean fuels. This is probably due to limited access to gas, low reliability of the electrical supply in rural areas, and the type of heating systems installed. The interviews broadened this explanation; we found that it was not only the frequency of blackouts, but also low voltage, that were key obstacles to switching to electricity. Many respondents claimed that low voltage prevented them from using electricity in the colder months, so they were forced to use coal to keep warm. At present voltage remains unmeasured, and official statistics only track the blackouts. Therefore, while the quantity of the supplied electricity matters for energy switching, more attention must also be given to the quality of the energy supply.

Another novel finding of this article, identified during the interviews, is that most households insulate their houses. However, the quality of the insulation has yet to be studied. Thus far, a number of studies by international organizations and independent research institutions have confirmed very high energy losses in large Soviet multistorey buildings (World Bank 2019). However, the energy efficiency of stand-alone houses is under-studied and could be a research topic for energy scholars in the region given its growing importance and the current knowledge gap.

By contrast, access to gas and education have significant positive effects on full fuel switching. While the impact of gas access is self-explanatory, the effect of education is more complex. Controlling for other variables (e.g. income), one possible explanation could be that higher levels of education increase the marginal cost of labour to heat living space. In other words, the cost of educated labour is higher than the cost of lifting a shovel and putting coal into the oven. Another possible explanation is the awareness of the negative health impacts associated with the use of traditional biomass and coal. Therefore, the current plan of the Kyrgyz government to increase gas access coverage to 60% by 2030 is likely to be an effective strategy in reducing air pollution. Information campaigns about the health impacts of polluting fuels could also be helpful. Improving the reliability of electrical energy supply might also increase the chances of a shift towards modern fuel use.

Another key message of the study is that raising the price of electricity might increase air pollution, both in cities and in rural areas. The Kyrgyz government, like those of many countries in Central Asia, faces the dilemma of whether to remove subsidies for energy prices or maintain social stability through low prices. However, with the growing reliance on solid fuels, raising electricity prices may intensify the already high air pollution in urban and rural areas. Therefore, if a price increase takes place, it should be accompanied by policies to improve residential energy efficiency, support for the poor to make the transition, access to gas, and information campaigns about the health and environmental risks of using polluting fuels.

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ORCID

Rahat Sabyrbekov http://orcid.org/0000-0001-5039-2602

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APPENDIX

Table A1. Volume of coal production and lignite (in thousand tonnes).

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Kyrgyz Republic	**321.3**	**395.6**	**491.8**	**606.9**	**575**	**830.7**	**1,163.9**	**1,407.9**	**1,811.90**	**1,928.70**
Batken oblast	139.4	132.6	157.1	148.9	156.5	179	190.4	213.8	203.6	249
Jalal-Abat oblast	23.3	26.5	46.6	51.1	49.5	53.3	88.5	153.5	230.9	159.8
Yssyk-Kul oblast	22.2	10.7	8.6	8.9	4.2	9.1	13.1	0.9	0.9	3.4
Naryn oblast	105.1	135.9	144.6	212.6	183.4	335.6	379.8	413.2	678.3	753.2
Osh oblast	31.3	89.9	135.0	185.5	181.4	253.5	491.8	625.5	698.1	763.2
Chui oblast	–	–	–	–	–	–	–	–	–	–
Bishkek City[1]				–	–	0.1	0.3	1.1	0.01	0.02

[1]Briquettes produced from coal; – denotes zero production.
Source: National Statistics Committee of the Kyrgyz Republic.

Table A2. Distribution of basic kinds of fuel and energy resources.

Items	2011	2012	2013	2014	2015
Motor-car petrol	**950**	**1,423**	**1,307**	**1,020**	**1,104**
Consumed	878	1,298	1,201	577	938
Exported	15	7	23	37	47
Losses	1	19	1	1	1
Bits and pieces at year end	56	99	82	405	118
Diesel fuel	**715**	**908**	**1,041**	**943**	**716**
Consumed	645	788	993	728	629
Exported	24	9	13	3	1
Losses	1	2	–	–	–
Bits and pieces at year end	45	109	35	212	86
Fuel oil	**243**	**169**	**127**	**322**	**505**
Consumed	183	110	71	285	387
Exported	12	3	3	–	–
Losses	–	–	1	–	–
Bits and pieces at year end	48	56	52	37	118
Electric power	**5,295**	**5,287**	**4,827**	**5,122**	**4,740**
Consumed	3,146	3,495	3,599	3,906	3,758
Exported	981	634	152	25	63
Losses	1,168	1,158	1,076	1,191	919
Bits and pieces at year end	–	–	–	–	–
Coal	**1,620**	**2,041**	**2,086**	**2,368**	**2,750**
Consumed	1,207	1,325	1,341	1,564	1,673
Exported	49	108	63	149	170
Losses	3	135	3	3	2
Bits and pieces at year end	361	473	679	652	905
Natural gas	**383**	**490**	**355**	**328**	**318**
Consumed	331	394	311	293	298
Exported	–	–	–	–	–
Losses	52	96	44	35	20

Source: National Statistics Committee of the Kyrgyz Republic.

Table A3. Fuel and energy resources (conditional fuel, thousand tonnes).

Items	2011	2012	2013	2014	2015
Total overall resources	**15,090**	**16,375**	**15,794**	**15,557**	**15,359**
Bits and pieces on beginning of year	673	552	821	812	867
Receipt (on import)	2,921	4,208	4,069	3,332	4,067
Other receipt	99	98	68	–	–
Booty (production)	11,397	11,517	10,836	11,413	10,425

Source: National Statistics Committee of the Kyrgyz Republic.

Table A4: Coal consumption in 2015 (in thousand tonnes).

Total consumption	100.0%	2,551.8
Agriculture, forestry and fishery	0.1%	3.8
Mining	24.1%	614.3
Processing industries	10.7%	272.2
Heating and energy generation	53.6%	1,366.5
Construction	1.3%	33.6
Trade and car repair	5.5%	139.9
Transport	0.1%	2.6
State, defence and social provision	3.3%	84.1
Education	0.3%	8.1
Healthcare and social service	0.6%	15.1
Other	0.5%	11.6

Source: National Statistics Committee of the Kyrgyz Republic.

A1. Interview questions (translated from the Kyrgyz language)

1. Name of the village/city and oblast?
2. Please rate your household's income status from 1 to 5, 1 being poor and 5 wealthy.
3. How many people including you live in your household?
4. How old are you?
5. Are you married?
6. How many people in your household are older than 55?
7. What is the size of your living area in square metres?
8. What is your primary source for household heating?
9. Do you combine other energy sources? If yes, which ones?
10. If you combine or use solid fuels only: why don't you use only electricity for heating?
11. Do you plan to use gas for heating if available?
12. Do you think your use of solid fuels for heating is bad for the health of your household members?
13. Are you concerned with the air pollution due to heating with solid fuels?
14. What are your monthly expenses for heating?
15. What is your occupation?
16. Would you like to provide any further comments related to household heating?

Table A5. Estimation results, relative risk ratios, rural.

	Multinomial probit	
VARIABLE	(3) No switching	(4) Full switching
Income	0.783***	0.997
	(0.025)	(0.066)
Household size	0.951***	0.935**
	(0.015)	(0.030)
Head's age	0.999	0.997
	(0.003)	(0.005)
Head with higher education	0.670***	1.116
	(0.052)	(0.161)
Head female	1.102	0.898
	(0.094)	(0.137)
Head married	0.995	0.628***
	(0.088)	(0.098)
Number of elderly members	1.100	0.936
	(0.067)	(0.119)

(*Continued*)

Table A5. Continued.

	Multinomial probit	
VARIABLE	(3) No switching	(4) Full switching
Dwelling size	0.999	0.982***
	(0.001)	(0.002)
Have access to gas	0.204***	2.182***
	(0.025)	(0.344)
Coal price	0.998***	0.998***
	(0.000)	(0.000)
Electricity Price	1.401	0.607
	(0.487)	(0.466)
Issyk-Kul	1.096	1.212
	(0.102)	(0.211)
Djalal-Abad	0.480***	1.048
	(0.041)	(0.171)
Naryn	0.911	0.781
	(0.081)	(0.162)
Batken	2.280***	2.930***
	(0.249)	(0.551)
Osh	1.167*	0.634**
	(0.104)	(0.134)
Talas	0.352***	0.857
	(0.030)	(0.138)
Dummy 2009	1.725***	1.960***
	(0.115)	(0.250)
Constant	8,208.179***	544.826***
	(5,734.374)	(731.267)
Observations	7,462	7,462

Notes: *p < 0.10, ** p < 0.05, *** p < 0.01.

Table A6: Estimation results, relative risk ratios, urban.

	Multinomial probit	
VARIABLE	(1) No switching	(2) Full switching
Income	0.723***	1.037
	(0.029)	(0.048)
Household size	0.959***	0.923***
	(0.015)	(0.017)
Head's age	0.998	0.989***
	(0.002)	(0.003)
Head with higher education	0.827***	1.342***
	(0.048)	(0.085)
Head female	0.859**	0.925
	(0.064)	(0.077)
Head married	0.886	0.746***
	(0.068)	(0.064)
Number of elderly members	1.020	0.787***
	(0.057)	(0.053)
Dwelling size	0.999	0.976***
	(0.001)	(0.001)
Have access to gas	0.395***	3.696***
	(0.026)	(0.242)
Coal price	0.999***	0.999***
	(0.000)	(0.000)
Electricity Price	1.311	0.372***
	(0.422)	(0.137)
Issyk-Kul	0.833**	0.609***
	(0.077)	(0.064)

(Continued)

Table A6: Continued.

	Multinomial probit	
VARIABLE	(1) No switching	(2) Full switching
Djalal-Abad	0.616***	0.932
	(0.056)	(0.085)
Naryn	0.426***	0.535***
	(0.041)	(0.058)
Batken	0.991	0.810**
	(0.096)	(0.085)
Osh	0.638***	0.765***
	(0.062)	(0.072)
Talas	0.386***	0.472***
	(0.038)	(0.053)
Chuy	1.858***	0.739**
	(0.212)	(0.093)
Dummy 2009	1.530***	1.296***
	(0.092)	(0.087)
Constant	2,686.014***	103.701***
	(1,804.399)	(79.065)
Observations	8,527	8,527

Notes: *p < 0.10, ** p < 0.05, *** p < 0.01.