Karymshakov, Kamalbek; Azhgaliyeva, Dina

Working Paper

Assessing the impact of income decline on household clean fuel choice: Evidence from the Kyrgyz Republic

ADB Economics Working Paper Series, No. 773

Provided in Cooperation with:
Asian Development Bank (ADB), Manila

Suggested Citation: Karymshakov, Kamalbek; Azhgaliyeva, Dina (2025) : Assessing the impact of income decline on household clean fuel choice: Evidence from the Kyrgyz Republic, ADB Economics Working Paper Series, No. 773, Asian Development Bank (ADB), Manila, https://doi.org/10.22617/WPS250119-2

This Version is available at:
https://hdl.handle.net/10419/322343

ASSESSING THE IMPACT OF INCOME DECLINE ON HOUSEHOLD CLEAN FUEL CHOICE

EVIDENCE FROM THE KYRGYZ REPUBLIC

Kamalbek Karymshakov and Dina Azhgaliyeva

NO. 773

April 2025

ADB ECONOMICS WORKING PAPER SERIES

ASIAN DEVELOPMENT BANK

ADB

ADB Economics Working Paper Series

Assessing the Impact of Income Decline on Household Clean Fuel Choice: Evidence from the Kyrgyz Republic

Kamalbek Karymshakov and Dina Azhgaliyeva

No. 773 | April 2025

Kamalbek Karymshakov (kamalbek.karymshakov@manas.edu.kg) is a professor at Kyrgyz-Turkish Manas University and Dina Azhgaliyeva (dazhgaliyeva@adb.org) is a senior economist at the Economic Research and Development Impact Department, Asian Development Bank.

ASIAN DEVELOPMENT BANK

6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 8632 4444; Fax +63 2 8636 2444
www.adb.org

ISSN 2313-6537 (print), 2313-6545 (PDF)
Publication Stock No. WPS250119-2
DOI: http://dx.doi.org/10.22617/WPS250119-2

ABSTRACT

Low-carbon energy transition, which includes the replacement of fossil fuels with low-carbon energy infrastructure, the removal of subsidies, and other measures, requires households to be able to pay for low-carbon energy services. Economic shocks such as the coronavirus disease pandemic and high inflation make paying for energy challenging for households. We use the Kyrgyz Integrated Household Survey data (2019–2021) to study the impact of income decline on energy consumption. We provide the following key results. First, the empirical results show that the effects of income decline on household energy consumption vary (positive or negative) according to income group. Second, the low-income group with income decline reduced energy consumption, while the higher income group (second quartile) increased energy consumption.

Keywords: household energy consumption, coal consumption, fossil fuel consumption, income decline, Central Asia, energy transition

JEL codes: Q41, Q31, Q48

1. INTRODUCTION

Household fuel combustion for cooking and heating contributes not only to global greenhouse gas emissions and outdoor air pollution, but also to household indoor air pollution, with adverse effects on health (Azhgaliyeva et al. 2021; Kapsalyamova et al. 2021; Azhgaliyeva, Kodama, and Holzhacker 2025). The transition to clean fuels requires households to have sufficient financial resources, including paying upfront costs to access new infrastructure and to change the house heating system and appliances. From this standpoint, it is very important to have household income stability and access to finance. The coronavirus disease (COVID-19) shock and economic volatility following the pandemic raised inflation, which in turn led to a loss of income for most households (Mendez Ramos and Lara 2022). An increase in poverty rates in developing countries has posed challenges and encouraged discussion regarding the transition into clean energy.

Most of the academic studies examining the energy consumption of households during pandemic-related lockdowns or restrictions note an increase in residential energy consumption, whereas overall energy consumption decreased during the initial COVID-19 period (Ai, Zhong, and Zhou 2022; Balest and Stawinoga 2022; Khalil and Fatmi 2022). Only a limited number of studies empirically investigate clean energy consumption by households under pandemic conditions. The existing literature focusing on energy consumption during the pandemic argues that residential energy consumption increased includes Kawka and Cetin (2021); Surahman et al. (2022); and Chen, Liao, and Zhang (2024). Recent studies highlight that mobility restrictions during the pandemic led to increased energy consumption by households (Mustapa et al. 2021, Rouleau and Gosselin 2021, Khalil and Fatmi 2022, Novianto et al. 2022, Surahman et al. 2022). However, in addition to the mobility restrictions, the impact of continuing income decline is important for understanding the energy consumption of households and the potential dynamics of the transition to clean energy.

To the best of our knowledge, there is no empirical evidence to show how changes in income during and after the pandemic restrictions affected the energy consumption of households in developing countries. Some studies explore the relationship between energy consumption and household income during the pandemic along with other factors in high-income countries (Zapata-Webborn et al. 2023). Overall, studies indicate that, in the context of the economic fluctuation following the pandemic, the socioeconomic dimensions of the transition to a low-carbon energy system are important and remain inadequately explored (Henry, Bazilian, and Markuson 2020; Tian et al. 2022). Income decline may result in the use of cheaper and solid fuels. However, this effect may differ according to the availability of energy sources and household income levels.

Central Asia's high energy consumption, reliance on air-polluting fuels, and old residential buildings (Sulaimanova, Azhgaliyeva, and Holzhacker 2024) are a cause of great concern for greenhouse gas emissions and air pollution. Many areas in Central Asia, including the Kyrgyz Republic, suffer from poor air quality as a result of heat production in the wintertime, including households' use of solid fuels, which contribute to outdoor and indoor air pollution (Azhgaliyeva et al. 2021, Kapsalyamova et al. 2021). The length of the heating season varies from 135 to 197 days, with the average temperature during said season ranging from +1.4°C to −6.9°C, with around 2,240–4,905 heating degree days[1] across the climatic zones[2] of the Kyrgyz Republic (Balabanyan et al. 2015, Azhgaliyeva et al. 2021). Air pollution contributes over 4,500 premature deaths in the Kyrgyz Republic per year (UNIDO 2019). At the same time, a sparse population is dispersed across a vast landmass, raising issues for energy infrastructure access (such as electrification and gas connectivity). Here, by energy infrastructure access we mean not only access to the infrastructure but also the quality of access, such as electricity blackouts and gas pressure (Azhgaliyeva et al. 2024).

This paper aims to examine the impact of the income decline in the post-COVID-19 period on household energy consumption in the Kyrgyz Republic—a lower middle-income economy in Central Asia. The Kyrgyz Republic experienced a rapid increase in the poverty level in 2021—up to 33.3% from 20.1% in 2019. The energy system of the country relies heavily on hydropower. In addition, there are large deposits of coal, whereas oil and gas resources are limited. Therefore, residential energy consumption draws mainly on electricity and coal. Meanwhile, domestic generation capacity is facing difficulties meeting growing demand for energy (IEA 2022). In addition, climate conditions mean that hydropower electricity production is susceptible to droughts and water supply fluctuations. This situation stresses the importance of the transition to alternative energy sources for sustainable economic development. However, currently, the Kyrgyz Republic faces widespread use of solid fuels by households, especially in rural areas (Kapsalyamova et al. 2021). These economic and energy conditions provide an interesting context to study the impact of an income decline on the energy consumption of households.

This study uses a panel dataset for 2019–2021 constructed from the nationally representative household survey, which enables us to analyze comparable households before and after the income decline. This study makes the following contributions to the academic literature on

[1] The number of heating degree days is an indicator equal to the product of the difference between the internal air temperature and the average outside air temperature for the heating period by the duration of the heating period (Azhgaliyeva et al. 2021).
[2] Balabanyan et al. (2015) divide the Kyrgyz Republic into three climatic zones, which are identified by the number of heating degree days per year (135, 160 and 197 heating degree days).

household energy consumption. First, it contributes to the scarce literature on the income shock and energy consumption nexus in a developing country context. Second, we study the impact of the decline across four main energy sources (coal, electricity, biomass, and gas) and by income quartile groups. This allows us to assess the heterogeneity of modern and solid fuel consumption trends among income groups.

The remainder of the paper is structured as follows. Sections 2 and 3 present the methodology and data. Section 4 discusses empirical results. Section 5 concludes with a summary of the results and policy implications.

2. METHODOLOGY

2.1. The Empirical Model

We study energy consumption of households that experienced an income decline in the aftermath of COVID-19. Energy consumption in 2020 and 2021 is compared with 2019 levels across households that faced an income decline and those without a loss of income. We use the Difference in Difference (DiD) method with household fixed effects (Shimizutani and Yamada 2021, Gupta and Kishore 2022). The DiD approach allows us to estimate the effect of treatment (which in our case is the income decline) through the comparison of outcomes before and after the treatment between those who experienced income decline (treatment group) and those who were not affected (control group). The following model is estimated:

$$y_{jt} = \beta_0 + \beta_1 P_t + \beta_2 I_{jt} + \beta_3 (P_t * I_{jt}) + \beta_4 X_{jt} + \mu_j + \epsilon_{jt}$$

where y_{jt} is the energy consumption of household j at year t. Energy consumption of a household is measured by total energy consumption and by types of energy sources, both converted into the unit of conventional fuel. P_t shows the post-treatment period, which takes the value of 1 if the year is 2020 and 2021, respectively. I_{jt} represents the treatment status of households measured as the dummy variable being equal to 1 if a household has a lower income in 2020 and 2021 compared with the previous year. Therefore, it measures whether household per capita income decreased during 2020 and 2021. Household income was deflated using the regional consumer price index for the relevant year. μ_j refers to the household fixed effects to consider unobservable and time-invariant heterogeneity. In all estimations, standard errors are clustered at the household level.

In the model specification, the coefficient β_1 measures the average difference in energy consumption in overtime periods in the analysis. Analogously, β_2 shows the difference in energy consumption between households of the treatment and the control groups. As the coefficient of the interaction term, β_3 is a DiD indicator and represents the treatment effect of household income decline on energy consumption of households in the treatment group compared with the control group before (2019) and after (2020 and 2021) the income shock. X_{jt} is the set of household head characteristics and, following the earlier empirical literature, includes sex, marital status, age, and education of household head (Zheng et al. 2014; Andersen et al. 2021; Han and Wei 2021; Chen, Liao, and Zhang 2024). Along with these, household characteristics include household size and number of preschool children (under 6 years of age).

Energy consumption is heavily dependent on climate conditions and, as a consequence of heating needs, use of coal and other solid fuels may be heightened during the winter. Therefore, households may differ in their consumption of fuel types according to regional differences in temperature (Filippín, Flores Larsen, and Mercado 2011; Li, Yang, and Lang 2012). To take into account this potential factor for energy consumption, we include in the model the mean annual temperature for regions of the Kyrgyz Republic (based on the National Aeronautics and Space Administration's MERRA-2 data[3]), among explanatory variables. Meanwhile, stable energy supply is another potential factor in the energy consumption of households (Meles 2020, Hashemi 2022). Therefore, along with annual mean temperature in the relevant region, we include in the set of explanatory variables the variable indicating how often households experience electricity outage.

2.2. Estimation with Matching

The DiD approach is based on the assumption of parallel trends of outcome variables between the treatment and the control groups. Comparison of mean values of energy consumption measures does not indicate a statistically significant difference of treatment and control groups (see Table A1 in the Appendix). Our data period is limited, with only one pre-intervention year, which restricts parametric testing based on longer pre-treatment periods. Moreover, a potential limitation in identification of the equation from the previous page is potential unobserved household characteristics that have an impact on both energy consumption and income shock, causing endogeneity. Although, the fixed effects included in the equation control for time-invariant unobservable characteristics, those that are time-varying may still have an impact.

[3] Modern-Era Retrospective analysis for Research and Applications, Version 2, available at https://power.larc.nasa.gov/data-access-viewer/ (accessed 21 December 2022).

Therefore, for robustness purposes, we estimate the DiD model on a matched sample of the treatment and control groups based on Coarsened Exact Matching (CEM) (Iacus, King, and Porro 2011; 2012). CEM is from the Monotonic Imbalance Bounding class of methods. It is designed to balance the treatment and control groups by the selected parameters via the exact matching algorithm. CEM reduces the level of imbalance between the two groups. Studies point out that DiD with matching provides better estimation results, and the matching approach helps in addressing endogeneity and selection bias (David, Rawley, and Polsky 2013; Sarkodie and Adom 2018; Do, Nguyen, and Grote 2019; Ryan et al. 2019).

For this matching, we use a set of variables consisting of sex, age, education, and marital status of household head; household size; number of children up to age 6; rural–urban location of household; and frequency of electricity outages experienced by the household. Construction of the treatment and control groups through the matching was implemented based on the pre-treatment values of 2019 data. The number of matched observations after the CEM is reduced to 2,376, of which 786 are in the treated group and 1,590 in the control group. Table A2 in the Appendix reports the L_1 statistics of the multivariate imbalance measure before and after the application of the CEM. After matching, this decreased from 0.67 to 0.43. The values of these statistics for almost all variables individually are almost zero. Based on these results, it can be argued that, after the CEM procedure, control and treated samples became more comparable.

While the CEM is an efficient approach in matching and constructing comparable treatment and control groups, this procedure is based only on observable characteristics of households. Therefore, one potential limitation of this study is that it does not fully address potential heterogeneity from unobservable differences.

2.3. Heterogeneous Effects

Income level is an important determinant of consumption behavior of households and energy consumption in both total and disaggregated components, and may vary by income groups of households (Hasan and Mozumder 2017, Ryan et al. 2019, Zou and Luo 2019). Therefore, to account for this potential difference, empirical analysis is applied by subsamples of the income quartile groups.

3. DATA

3.1. Source of Data

We use data from the Kyrgyz Integrated Household Survey (KIHS) conducted by the National Statistical Committee of the Kyrgyz Republic. The survey is conducted quarterly and is nationally representative, with the household head or a knowledgeable member the main respondent. Modules in the survey cover multi-topic information such as household roster, income, expenditure, consumption, employment, and household assets. For our research purposes, quarterly data are aggregated into annual values and panel data constructed at the household level using the survey data for 2019–2021. Data for 2019 are considered as providing pre-COVID-19 information, and those from 2020 and 2021 as data during the COVID-19 period.

KIHS surveys about 5,000 households each year. A household identifier in all three waves of the survey is used for the construction of the panel dataset. We have balanced panel data with the sample size of 4,485 households each year, or a total of 13,455 observations in panel data.

3.2. Construction of Key Variables

Income

In the survey, the income of a household is recorded on a monthly basis, and all types of incomes are aggregated into annual values. All income sources are taken into account, including wage earnings, social transfers, sale of assets, rental income, remittances and other income types. In order to determine if the income of a household has declined compared with the previous year, annual nominal income of households is deflated based on the consumer price index for the relevant regional location. Based on this information, we created a dummy variable indicating income decline if, in both 2020 and 2021, a household experienced lower real income than in the previous year. Out of a total sample of 4,485 observations, 1,213 households, or 27% of the total sample, were identified with income decline status.

Energy Consumption (per capita)

Energy consumption in the data is identified in the section on housing and utility expenses, under the question "*What type of fuel did you purchase and how did you use it?*" Answers include the amount of fuel purchased, provided as aid, or prepared by themselves and reserved from the previous period (by fuel type). Therefore, to focus on the consumed quantity of fuel types, all three options are used: purchased, taken as aid, and reserved/prepared by themselves. This section is specified for types of fuel such as coal, wood, gas, liquified petroleum gas (LPG), brush, corn bud,

and dung. The quantity of the electricity consumed is estimated from the expenditure records and converted into the kilowatt hour (kWh) using the price per kWh.[4] The absolute quantity of each energy source may not be relevant for the comparison across energy sources.

Following Zou and Luo (2019) and the methodology of the National Statistical Committee of the Kyrgyz Republic (NSCKR 2021), the consumption amount of each energy source was converted into the unit of fuel equivalent. Fuel equivalent is a unit of measurement of different energy sources with respect to the calorific value of 1 kg of coal equivalent (kgce) being equal to 29.3 megajoules (MJ) or 7,000 kilocalories (kcal) (NSCKR 2021). Table 1 presents the coefficients of conversion of energy types into the fuel equivalent. This approach allows us to focus on total energy consumption by type of energy sources. Corn bud, wood, brush, and dung are grouped under the heading of biomass. Gas and LPG are combined into a single category as gas. Therefore, we focus on the following four types of energy: coal, electricity, biomass, and gas. All energy types consumed are estimated in per capita terms. Energy consumption is divided by the household size to calculate energy consumption per capita.

As we can see from Table 1, a major energy source for households is coal, accounting for about 45%. The second major source is electricity. Together, these account for about 77% of total energy consumed. Electricity, with more than 1,988 kWh per capita annually, represents more than 31% of total energy consumption in total fuel equivalent estimations. Gas represents 7% of total energy consumed by households in the Kyrgyz Republic, though liquid gas in cylinders has a very low share. Biomass components have more than 16% share in total energy consumption. Among them, dung represents the highest share; it is especially important for rural households.

Table 1: Energy Sources by Physical Amount and in Fuel Equivalent

	Physical Amount (mean)	Coefficient of Fuel Equivalent	Fuel Equivalent (mean kgce)	Share in Total Fuel Equivalent
Coal	2,280 kg	0.5	10.1	45.4
Electricity	1,988.5 kWh	0.3	685.0	31.1
Gas	112.7 m^3	1.2	130.0	5.9
Liquid gas cylinders	13.0 kg	1.6	20.4	0.9
Wood	1.7 m^3	0.3	0.4	0.0
Brush	210.6 kg	0.5	105.3	4.8
Corn bud	386.2 kg	0.3	127.4	5.8
Dung	375.3 kg	0.4	135.1	6.1

kg = kilogram, kgce = kilogram of coal equivalent, m^3 = cubic meter, kWh = kilowatt hour.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

[4] The standard price for electricity was 0.77 som per 1 kWh up to 700 kWh and 2.16 som per 1 kWh after 700 kWh.

3.3. Descriptive Statistics

Table 2 presents descriptive statistics of variables used in the estimations. Figure 1 shows energy consumption of households by income decline status: 27% of all households in the sample experienced an income decline in 2020 and 2021.

Total average energy consumption of households differs between the two groups of households. Those with loss of income demonstrate lower total consumption and, interestingly, slightly higher use of electricity and gas than those households that did not experience a reduction of income. Energy consumption by survey years shows that households with income decline significantly increased total energy consumption in the year of the COVID-19 outbreak, potentially related to increased consumption of coal (see Figure 1). However, in 2021, this consumption decreased again. Electricity consumption increased gradually throughout the observed period. Households without income shock demonstrated an increase in total energy consumption not in 2020 but rather in 2021. During the second year of COVID-19, they showed an increase in average coal and electricity consumption. Biomass and gas consumption patterns do not demonstrate significant differences between the two groups of households. However, these visual inspections of the descriptive statistics do not confirm the causal relationship.

Table 2: Descriptive Statistics

	Full Sample		Households with Income Decline		Households with No Income Decline	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Income decline (1=income decline)	0.27	0.44				
Total household energy consumption per capita (fuel equivalent kgce)	1,432.33	8,566.11	1,354.36	5,623.71	1,461.24	9,426.47
Coal (kgce)	1,000.11	10,392.23	966.88	7,118.62	1,010.91	11,253.37
Electricity (kgce)	685.05	534.93	694.64	516.70	681.49	541.51
Biomass (kgce)	63.57	155.82	60.72	145.76	64.50	158.96
Gas (kgce)	99.01	197.49	103.43	179.59	97.42	203.57
Household head characteristics						
Sex (1=female)	0.40	0.49	0.39	0.49	0.40	0.49
Age	56.05	13.42	57.99	13.82	55.33	13.20
Marital status (1=married)	0.62	0.48	0.623	0.485	0.625	0.484
Education level (%):						
Primary education and below	2.96		3.35		2.81	
Secondary general	53.71		52.46		54.18	
Technical education	25.17		23.85		25.66	
Tertiary education	18.16		20.34		17.35	
Household size	4.10	2.10	3.91	2.08	4.18	2.11
Number of children (0–5 years)	0.45	0.77	0.37	0.70	0.48	0.79
Electricity outage (1=never; 2=several times in a month or year; 3=several times in a week)	1.9	0.38	1.9	0.38	1.9	0.39

Continued on the next page

	Full Sample		Households with Income Decline		Households with No Income Decline	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Mean annual temperature (°C)	6.41	4.38	6.63	4.38	6.33	4.38
Urban (1=located in urban area)	0.57	0.50	0.58	0.49	0.57	0.50

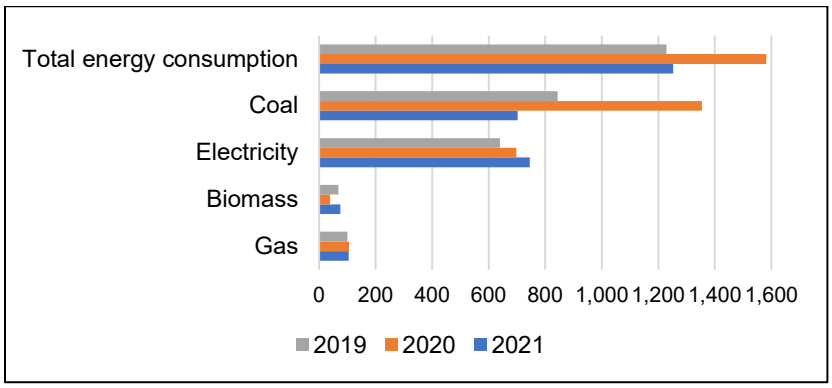
kgce = kilogram of coal equivalent.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

A total of 40% of households in the sample were headed by women. Although there is no large difference by income status, households with income decline had a slightly lower share of female household heads, at 39%. On the other hand, 3.35% of household heads among households with income decline had primary education and below, while in the total sample this rate was lower, at 2.9%. Analogously, technical education of heads was lower among these households. Families without income shock had higher household size and a relatively large number of children. Electricity outages did not show significant difference between households by income status. However, overall, the value of this was greater than 1, suggesting that most households experienced electricity outages at least several times during a year or in a month.

Other household characteristics indicate that, on average, in households that saw income decline, the household head is older and the household size is comparatively lower with a smaller number of children under 6 years of age. Also, these households are more concentrated in urban areas and the average annual temperature is slightly higher.

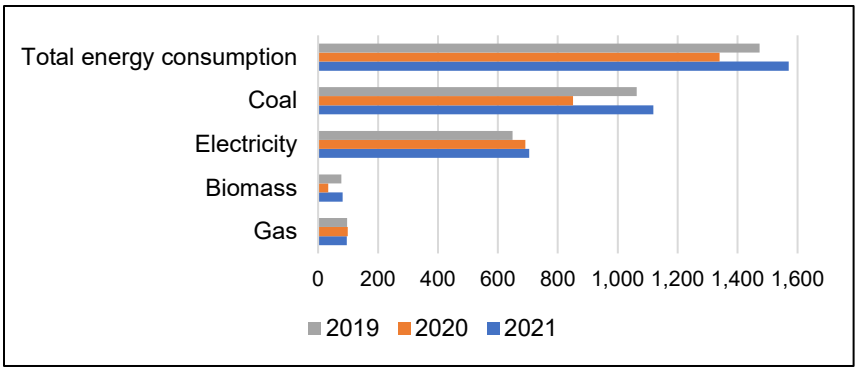
Figure 1: Household Energy Consumption per capita by Income Status

a) Households with Income Decline (kgce)



Continued on the next page

b) Households with No Income Decline (kgce)



kgce = kilogram of coal equivalent.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

4. RESULTS AND DISCUSSION

4.1. Impact of Income Decline on Energy Consumption

Table 3 presents estimation results for the total sample by source of energy (coal, electricity, biomass and gas). Our main variable of interest—interactions of years and the dummy variable of income decline— reflects the average difference in the effect of income decline on energy consumption between the treated and the control groups.

Empirical findings demonstrate that, after controlling for household characteristics, total energy consumption does not show any difference. However, households with income decline showed increased consumption of biomass in 2020. This result is in line with the general expectation that, given the income decline, households may have been prone to use low-price/free energy sources.

However, on the other hand, the dummy variable by years shows that, generally, households (without considering income decline status) used less biomass in 2020, whereas in 2021 usage increased. Consumption of electricity in both years indicates a growing trend. These effects can be explained by the fact that lockdown measures during the pandemic increased general residential electricity consumption. This is in line with studies that point to increased electricity consumption during the pandemic related to the lifestyle of households under lockdown measures (Abdeen et al. 2021, Khalil and Fatmi 2022, van Zoest et al. 2023). However, the general economic downturn in the second year of the pandemic may have created more incentives for households to focus on biomass.

Other explanatory variables are mainly as expected. Households with female heads are inclined to use more electricity and less biomass. This result is consistent with existing literature showing that women-headed households and women's empowerment is positively associated with modern energy use (Li et al. 2023; Chen, Liao, and Zhang 2024; Yan et al. 2024). This can be explained by the fact that collection of biomass requires relatively greater physical effort, whereas, given 100% available access to electricity in the Kyrgyz Republic, households with female heads opt out of the time-consuming use of biomass. This evidence is consistent with the existing literature showing that lower reliance on biomass may contribute to better outcomes for women with time and health status (Heltberg 2005). Marital status increases both electricity and biomass consumption, which is in line with previous studies that underline this factor as one of the main characteristics of energy consumption behavior (Pelenur and Cruickshank 2012).

Education does not show a statistically significant (at 5% level of significance) effect on energy consumption. These results are unexpected as the previous findings show that households with better-educated household heads are more likely to use modern and convenient fuels due to a greater awareness about the adverse impact of air polluting fuels (Alem et al. 2016) and greater opportunity costs associated with using time-consuming traditional stoves (Azhgaliyeva, Kodama and Holzhacker 2025).

Table 3: Effect of Income Decline on Energy Consumption

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
2020*Income decline	465.800	707.242	3.617	10.717**	2.444
	(363.941)	(564.651)	(7.940)	(4.950)	(5.421)
2021*Income decline	-144.584	-233.250	7.154	-4.734	0.641
	(294.805)	(431.296)	(9.969)	(3.869)	(5.146)
2020	-240.007	-512.102	67.967***	-10.367***	1.705
	(446.566)	(721.979)	(7.706)	(3.322)	(5.493)
2021	62.097	-7.317	66.470***	10.517***	-1.639
	(326.517)	(442.797)	(6.244)	(2.399)	(2.954)
Sex of household head (1=female)	87.358	28.358	45.979*	-16.185**	24.084
	(173.908)	(247.590)	(26.578)	(7.930)	(16.577)
Age of household head	3.660	5.464	-1.070	-0.228	-0.324
	(7.163)	(10.019)	(1.233)	(0.285)	(0.502)
Marital status	-126.440	2.010	-109.440***	-38.486***	-32.978***
	(147.290)	(208.481)	(31.282)	(11.557)	(12.621)
Education of household head (base category=tertiary education)					
Primary education and below	-67.478	-16.940	-22.768	0.625	-7.762
	(156.350)	(226.271)	(59.973)	(13.688)	(41.432)
Secondary general	181.094*	203.321	52.519	-2.227	30.421
	(102.282)	(138.575)	(44.180)	(9.577)	(43.132)

Continued on the next page

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
Technical education	66.248	42.224	47.374	12.051	9.487
	(99.937)	(138.911)	(50.360)	(9.934)	(43.551)
Household size (person)	-340.123***	-212.185	-151.073***	-10.927***	-16.079***
	(127.802)	(155.736)	(9.746)	(2.347)	(2.650)
Number of children (0–5 years)	198.117	212.543	35.628***	-4.542*	6.678**
	(194.784)	(242.197)	(7.197)	(2.670)	(2.896)
Electricity outage	97.737	166.084	-8.085	-2.164	-6.238
(1=never to 5=several times in a week)	(118.138)	(178.040)	(8.597)	(3.367)	(4.851)
	-98.963	-315.593	29.559***	35.887***	0.364
Mean annual temperature	(262.427)	(516.722)	(6.247)	(3.676)	(3.429)
	44.485	53.084	-5.189	5.847	-4.403
Urban	(80.320)	(73.520)	(38.690)	(13.757)	(7.768)
	-340.123***	-212.185	-151.073***	-10.927***	-16.079***
Household fixed effects	+	+	+	+	+
Constant	2,919.500	3,368.595	1,142.857***	-84.627**	175.555***
	(1,901.264)	(3,857.275)	(92.286)	(33.162)	(43.374)
Observations	13455	9063	13455	8628	4467
R-squared	0.001	0.001	0.171	0.101	0.020

Standard errors in parentheses. Robust standard errors. *p < 0.10, ** p < 0.05, *** p < 0.010. Standard errors are clustered at the level of the household.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

Household size has a negative impact on consumption of energy per capita (total energy and almost all energy sources with the exception of coal). This means that larger households consume more coal per capita, but less of other energy sources. Although other empirical studies argue that household size increases demand for energy (Ngui et al. 2011), our result with the negative impact of household size on total energy consumption per capita does not contradict. On the other hand, a higher number of children at home below 6 years of age has a strong positive impact on electricity consumption per capita. Evidently, this is related to childcare activities and spending more time at home.

Among other factors, rural–urban location and quality of electricity access (electricity outage) do not show a statistically significant effect. The existing literature shows that the quality of electricity access affects the fuel choice (Azhgaliyeva et al. (2021), but does not affect energy consumption in the short term (according to our results over 2019-2021).

Table 4 reports the results of the main variables of interest of DiD from estimations based on the coarsened exact matching. The results are mainly consistent with the unmatched full sample estimations. Year dummies indicate analogous effect in electricity and biomass consumption. However, the unmatched sample interaction of the 2020-year dummy and income decline does not demonstrate a statistically significant effect in biomass consumption. This may be the result of the lower sample size after the matching procedure.

Table 4: Effect of Income Decline on Energy Consumption Using Coarsened Exact Matching

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
2020*Income decline	359.526	609.007	15.843	7.541	-0.026
	(404.269)	(687.385)	(11.890)	(6.792)	(7.950)
2021*Income decline	-542.066	-867.392	14.094	-4.313	3.764
	(461.374)	(695.616)	(14.361)	(5.051)	(6.689)
2020	531.246	803.062	73.135***	-12.276**	0.412
	(501.473)	(876.852)	(12.533)	(5.136)	(8.107)
2021	623.013	765.725	72.137***	9.683***	-7.963*
	(565.794)	(785.135)	(10.707)	(3.601)	(4.065)
Household fixed effects	+	+	+	+	+
Observations	7128	4686	7128	4518	2370
R-squared	0.003	0.004	0.214	0.098	0.021

Standard errors in parentheses. Robust standard errors. *p < 0.10, ** p < 0.05, *** p < 0.010.
Note: Each regression includes household controls such as household size; number of children (0–5 years); household head sex, age, marital status, and education level; electricity outage; mean annual temperature; and urban–rural. Standard errors are clustered at the level of the household.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

4.2. Effects by Income Group

The impact of income decline on energy consumption can vary by income group. The total sample was classified into quartile income groups based on yearly per capita household income. In order to understand the potential effect of income decline on energy consumption by income level, estimations were applied to the sample of each quartile group. Table 5 presents the results. The first quartile group refers to the lowest income; the fourth quartile is the highest income group.

Table 5: Effect of Income Decline on Energy Consumption by Income Group

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
First quartile (low income)					
2020*Income decline	-609.458**	-739.640**	-3.110	-1.811	-5.940
	(269.660)	(331.237)	(8.346)	(6.881)	(4.190)
2021*Income decline	-481.804	-576.132	-9.581	3.216	2.077
	(397.141)	(487.543)	(10.129)	(5.600)	(7.395)
2020	369.773	394.281	9.838	-3.767	8.436
	(613.177)	(724.503)	(7.723)	(5.512)	(9.677)
2021	428.617**	477.520*	33.432***	2.644	-0.712
	(209.585)	(257.297)	(5.505)	(2.930)	(2.877)
Second quartile					
2020*Income decline	1,085.900**	1,547.724**	-12.503	1.756	12.973
	(445.882)	(635.072)	(10.811)	(11.487)	(8.579)
2021*Income decline	659.960*	873.939*	-2.741	-10.567	12.602
	(396.711)	(522.863)	(12.909)	(12.495)	(12.120)

Continued on the next page

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
2020	-786.976	-991.710	24.731*	3.771	7.631
	(605.827)	(878.795)	(12.651)	(8.811)	(9.144)
2021	-541.057	-750.419	38.584***	15.331***	-4.177
	(414.287)	(520.492)	(8.231)	(5.235)	(5.455)
Third quartile					
2020*Income decline	-715.731	-1324.800	9.034	12.721	-31.979
	(463.836)	(848.253)	(15.312)	(13.766)	(21.926)
2021*Income decline	-1,564.368**	-2810.467**	51.705***	7.555	-9.675
	(773.111)	(1332.629)	(17.288)	(9.538)	(10.321)
2020	664.699	465.283	99.153***	-11.356	17.490
	(477.363)	(1,246.220)	(16.673)	(8.510)	(28.108)
2021	1,183.870**	1,621.899*	73.276***	3.764	0.429
	(597.097)	(859.505)	(11.255)	(5.356)	(6.622)
Fourth quartile (high income)					
2020*Income decline	1,383.179	2,514.368	17.064	38.640***	16.895**
	(909.707)	(1,685.776)	(17.557)	(11.575)	(7.813)
2021*Income decline	-43.479	-204.882	14.568	-6.370	13.101*
	(998.157)	(1,879.448)	(22.115)	(10.077)	(7.909)
2020	-1318.611	-2799.977	103.884***	-26.439***	-0.881
	(1,466.428)	(2,850.001)	(16.974)	(8.105)	(6.466)
2021	-482.121	-917.833	85.416***	16.687**	-7.590
	(1,151.239)	(1,860.718)	(14.768)	(7.726)	(4.782)

Standard errors in parentheses. Robust standard errors. *p < 0.10, ** p < 0.05, *** p < 0.010.
Note: Each regression includes household controls such as household size; number of children (0–5 years); household head sex, age, marital status, and education level; electricity outage; mean annual temperature; and urban–rural. Standard errors are clustered at the level of the household.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

The results show that the poorest households with income decline reduced coal consumption during the first year of the pandemic as a result of income shock, probably by heating/cooking less and switching to free energy sources. Interestingly, income shock had a positive effect on households in the second quartile by increasing coal consumption in both years, though the effect in 2021 was statistically less significant. Households with income decline in the third quartile in 2021 reduced coal and, in exchange, increased electricity consumption, resulting in a reduction in overall energy consumption. Income declines affected households in the highest income quartile to increase consumption of biomass and gas during the first year of the pandemic, probably in response to the need to spend more time at home and to cook more at home.

Table 6: Effect of Income Decline on Energy Consumption by Income Group Using Coarsened Exact Matching

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
First quartile (low income)					
2020*Income decline	-796.353**	-976.490**	-12.619	2.479	-17.050
	(351.028)	(434.572)	(14.408)	(9.319)	(14.688)
2021*Income decline	-240.843	-342.956	-15.744	4.434	17.498
	(414.218)	(547.578)	(15.708)	(7.738)	(19.918)
2020	733.414	822.763	24.632	-5.833	37.124
	(610.272)	(679.866)	(19.488)	(7.492)	(33.530)
2021	431.458*	473.672	43.011***	-1.549	-5.670
	(255.679)	(314.026)	(9.831)	(4.472)	(7.457)
Second quartile					
2020*Income decline	782.026*	1264.071*	-18.019	-7.679	39.427
	(447.543)	(725.633)	(17.058)	(15.322)	(31.285)
2021*Income decline	196.919	329.184	-13.448	-8.554	54.693
	(149.249)	(230.754)	(19.958)	(16.756)	(43.912)
2020	100.065	280.938	34.709	-18.209	39.263
	(362.445)	(651.218)	(24.729)	(16.571)	(27.586)
2021	-2.882	-51.975	49.764***	17.971	-18.393
	(131.357)	(144.361)	(13.838)	(12.699)	(18.148)
Third quartile					
2020*Income decline	-508.037	-837.322	6.572	-7.596	-44.579
	(426.950)	(785.078)	(21.967)	(17.027)	(34.550)
2021*Income decline	-896.745**	-1,634.353**	50.479*	8.761	-15.438
	(370.898)	(672.998)	(26.249)	(11.799)	(14.607)
2020	994.026*	1,333.001	112.640***	1.851	29.313
	(532.027)	(1,171.704)	(29.796)	(14.434)	(43.996)
2021	978.452***	1,356.119***	77.598***	2.743	8.762
	(323.670)	(506.381)	(21.145)	(7.923)	(27.185)
Fourth quartile					
2020*Income decline	811.839	1,555.223	23.345	35.841**	7.944
	(572.579)	(1,237.129)	(23.952)	(15.914)	(9.774)
2021*Income decline	-1,393.393	-2,944.780	39.491	-2.668	12.150
	(1,334.954)	(2,565.356)	(30.530)	(11.497)	(8.774)
2020	440.839	745.994	99.441***	-27.488***	-7.745
	(1,406.023)	(2,901.534)	(27.154)	(9.377)	(7.516)
2021	1,169.436	1,720.912	80.236***	14.443*	-15.468***
	(1,686.025)	(2,641.345)	(25.620)	(7.566)	(5.960)

Standard errors in parentheses. Robust standard errors. *p < 0.10, ** p < 0.05, *** p < 0.010.
Note: Each regression includes household controls such as household size; number of children (0–5 years); household head sex, age, marital status, and education level; electricity outage; mean annual temperature; and urban–rural. Standard errors are clustered at the level of the household.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

Overall, taking into account status regarding income decline, households demonstrate growth in electricity consumption. In particular, households in the third and fourth quartiles demonstrate strong growth per capita in electricity consumption in both 2020 and 2021. A positive effect on

biomass consumption is observed among households in the second and fourth quartiles. However, the highest income group households showed decreasing biomass consumption during the first year of the pandemic.

Estimation results of the same model based on the matched sample are similar to regression results on the unmatched sample (see Table 6). However, the variable in the third income quartile group does not show a statistically significant impact on electricity, whereas in the fourth group it is not significant for gas consumption. Another difference is that households in the fourth quartile in 2021 reduced gas consumption.

Thus, income decline during the pandemic had varying effects on energy consumption. Households with income shocks during the first year of the pandemic increased biomass consumption, though total energy consumption did not change. This is in line with the general expectation that falling income may cause households to rely more heavily on less costly energy sources, which are generally solid fuels which cause indoor air pollution (dirty fuels). Nevertheless, empirical results are heterogeneous across income levels. Households in the lowest income group reacted to an income decline by reducing total energy consumption and coal consumption, whereas those in the second quartile increased coal consumption. Spending more time at home during the pandemic, in the context of falling income, may have created more incentives for switching to lower-price fuel. An analogous decline in total energy consumption is observed among households with income shock in the third quartile. This effect is associated with the decrease of coal and higher consumption of electricity. Interestingly, those households with income shock in the highest income group increased biomass and gas consumption. This may be associated with larger residential space and location characteristics, where access to heating and cooking fuels is based mainly on traditional sources, with some having access to gas. This particular finding stresses the importance of a supply of clean fuel types, the absence of which leads to the use of dirty fuels even under the high-income conditions.

On the other hand, year dummies indicate that, if we do not focus on income decline status of households, then we see a general tendency toward higher consumption of electricity, which is strongly evident among higher income groups. This may be due to growing demand for energy overall. But it may also suggest some movement toward cleaner energy among higher income groups. However, there is not enough evidence on the sustainability of this movement, as it may be related to households' ability to afford electricity amid limited supply and to availability of gas and coal. The findings for households with the lowest income quartile to some extent confirm this statement. Under income decline conditions, these households decreased coal consumption,

thus experiencing lower overall energy consumption per capita. Therefore, negative income shocks cause lower energy consumption among poor households and intensify energy poverty.

4.3. Robustness Analysis: Income Decline Magnitude

In our baseline model estimations income shock is specified as the fact of lower income in 2020 and 2021 than income of the previous year. However, one may argue such approach for measuring the income shock is general and does not ensure if results are sensitive to different magnitude of income decline. Because household energy consumption behavior may vary by the magnitude of income shock. Following, this potential source of heterogeneity alternative specification of income decline is based on average percentile decline of income in consecutive 2020 and 2021 years. Distribution of households that experienced income shock presented in Figure A1 in Appendix show that in two years most of the households saw decline by 20%, and even higher intensity is observed by 10% magnitude. Therefore, we used three thresholds for our further alternative model specifications: relatively small income declines by 10%, modest income shock by 20% and severe income fall with more than 20%.

Results of estimations for the total sample are presented in Table 7. In general the results are in line with baseline model estimations. Households with severe income reduction by more than 20% showed increased biomass consumption during the first year of shock. Though, this effect demonstrated less statistical significance. Analogous findings can be noted for households with income decline up to 10%. However, interestingly households with severe income fall showed a statistically significant reduction of biomass consumption in 2021.

Table 7: Impact of Income Decline Magnitude on Energy Consumption

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
2020*Income decline by 10%	932.908*	1657.744*	11.056	9.850	-1.408
	(546.271)	(991.194)	(10.086)	(7.544)	(6.096)
2020*Income decline by 20%	-134.124	-215.964	-5.551	7.529	16.964
	(421.928)	(608.037)	(11.979)	(7.321)	(10.768)
2020*Income decline by more than 20%	31.986	41.534	-3.498	15.011*	-1.940
	(331.207)	(470.735)	(15.271)	(7.824)	(6.460)
2021*Income decline by 10%	9.481	32.920	11.259	-5.156	-2.728
	(279.965)	(414.006)	(11.840)	(5.185)	(5.723)
2021*Income decline by 20%	-476.082	-691.441	-14.831	4.586	6.706
	(442.788)	(635.615)	(14.617)	(5.864)	(10.028)

Continued on the next page

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
2021*Income decline by more than 20%	-155.797	-229.027	19.901	-13.426**	2.876
	(336.957)	(476.896)	(23.543)	(6.785)	(9.401)
2020	-239.967	-521.286	68.070***	-10.482***	1.569
	(447.034)	(723.099)	(7.737)	(3.318)	(5.528)
2021	61.153	-11.402	66.446***	10.532***	-1.726
	(326.700)	(442.985)	(6.253)	(2.400)	(2.979)
Sex of household head (1=female)	96.485	31.971	46.072*	-16.109**	24.193
	(175.899)	(251.537)	(26.540)	(7.885)	(16.601)
Age of household head	4.106	6.132	-1.028	-0.248	-0.304
	(7.006)	(9.936)	(1.232)	(0.287)	(0.504)
Marital status	-112.140	12.659	-108.628***	-38.958***	-32.557**
	(150.473)	(216.101)	(31.201)	(11.531)	(12.743)
Basic education	-51.631	-43.258	-23.643	1.449	-7.933
	(152.589)	(222.171)	(59.835)	(13.696)	(41.518)
Secondary general	182.720*	171.730	51.726	-1.481	30.237
	(98.340)	(129.418)	(44.106)	(9.401)	(43.179)
Technical education	49.403	-20.356	46.529	12.825	9.508
	(96.433)	(131.174)	(50.269)	(9.737)	(43.591)
Household size (person)	-338.220***	-206.288	-150.541***	-11.261***	-15.790***
	(128.567)	(155.311)	(9.814)	(2.343)	(2.724)
Number of children (0–5 years)	200.348	213.748	35.496***	-4.406	6.361**
	(195.136)	(241.592)	(7.170)	(2.680)	(2.930)
Electricity outage (1=never to 5=several times in a week)	108.334	187.344	-8.017	-2.226	-6.387
	(118.877)	(180.254)	(8.594)	(3.403)	(4.833)
Mean annual temperature	-98.639	-324.768	29.679***	35.752***	0.237
	(262.978)	(518.163)	(6.276)	(3.671)	(3.468)
Urban	73.025	103.626	-4.086	5.315	-4.416
	(81.382)	(83.333)	(38.873)	(13.915)	(7.748)
Household fixed effects	+	+	+	+	+
Constant	2837.693	3334.017	1136.953***	-81.084**	174.383***
	(1889.17)	(3853.12)	(92.415)	(33.136)	(43.211)
Observations	13455	9063	13455	8628	4467
R-squared	0.001	0.001	0.171	0.102	0.021

Standard errors in parentheses. Robust standard errors. *p < 0.10, ** p < 0.05, *** p < 0.010. Standard errors are clustered at the level of the household.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

Estimations results by income group presented in Table 8. Households in lowest income group with 10% income fall demonstrated reduction in total energy and coal consumption. This finding underlines the vulnerability of the lowest income group to energy consumption. But households

with relatively small and severe income decline in the second quartile increased their total energy and coal consumption in 2020. Increased electricity consumption is observed among households in the third quartile who saw income reduction by 10 and more than 20%. Households with income declined by 10% in highest income group increased biomass consumption during the first year, whereas those with 20% reduction of income increased gas consumption in the same period. However, these results did not reveal changes in energy consumption behavior among those with severe income shock. These findings confirm previous results from the baseline model estimations disaggregated by income level.

Table 8: Impact of Income Decline Magnitude on Energy Consumption by Income Group

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
First quartile (low income)					
2020*Income decline by 10%	-757.887***	-929.977***	-6.998	-2.759	-7.305*
	(251.309)	(311.725)	(9.776)	(10.550)	(3.971)
2020*Income decline by 20%	-468.687	-530.656	11.353	-13.591	-3.538
	(435.193)	(568.479)	(12.593)	(10.353)	(4.931)
2020*Income decline by more than 20%	-257.465	-335.481	-5.475	9.355	-2.887
	(429.508)	(509.831)	(19.796)	(10.302)	(6.162)
2021*Income decline by 10%	-575.305	-697.281	-15.658	4.455	-3.942
	(390.128)	(487.168)	(12.005)	(6.516)	(8.301)
2021*Income decline by 20%	-771.444*	-974.960*	23.972	-8.800	6.418
	(414.558)	(525.284)	(17.544)	(6.544)	(7.385)
2021*Income decline by more than 20%	15.278	19.961	-18.947	11.358	10.309
	(706.375)	(829.824)	(22.965)	(14.430)	(7.179)
Second quartile					
2020*Income decline by 10%	1311.009**	2023.257**	-7.918	3.389	13.788*
	(535.189)	(864.254)	(11.866)	(16.962)	(8.202)
2020*Income decline by 20%	558.792	780.244	-14.043	-7.768	3.160
	(400.022)	(521.201)	(20.822)	(14.608)	(11.968)
2020*Income decline by more than 20%	959.260*	1226.513**	-15.108	11.871	34.872***
	(505.128)	(622.107)	(25.754)	(10.623)	(13.402)
2021*Income decline by 10%	600.361	824.673	-10.970	-13.213	11.659
	(390.260)	(525.158)	(13.987)	(16.355)	(13.345)
2021*Income decline by 20%	760.624	944.442	16.890	-1.723	11.073
	(511.438)	(625.447)	(25.815)	(15.120)	(12.363)
2021*Income decline by more than 20%	767.260	930.788	34.874	-31.133	33.075**
	(518.870)	(674.023)	(39.235)	(23.000)	(15.700)
Third quartile					
2020*Income decline by 10%	-17.946	89.526	4.554	3.874	-34.495
	(285.908)	(573.598)	(18.023)	(20.240)	(23.907)
2020*Income decline by 20%	-2389.697	-3761.238	-1.519	14.343	-22.220
	(2002.979)	(3053.338)	(15.889)	(17.167)	(23.989)
2020*Income decline by more than 20%	-1326.740	-2073.039*	30.328	28.662	-29.022
	(855.810)	(1216.619)	(38.601)	(23.396)	(20.264)

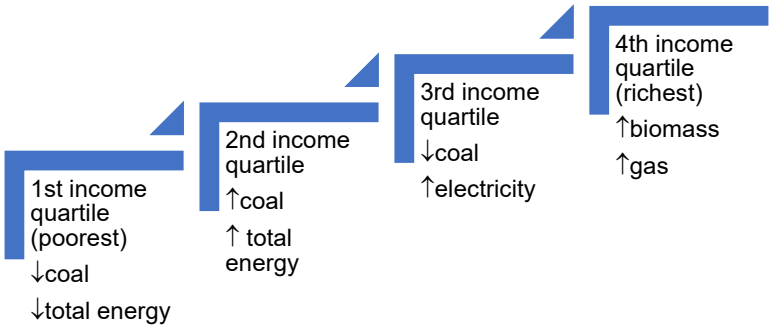
Continued on the next page

	Total Energy Consumption	Coal	Electricity	Biomass	Gas
2021*Income decline by 10%	-988.347*	-1630.935*	40.890**	8.959	-14.091
	(557.878)	(881.091)	(18.399)	(13.018)	(11.705)
2021*Income decline by 20%	-3482.474	-5436.059	-21.929	16.024	10.844
	(2381.168)	(3595.159)	(20.555)	(10.518)	(18.407)
2021*Income decline by more than 20%	-1845.673	-3322.351	221.125***	-21.958	-10.702
	(1329.580)	(2109.009)	(67.079)	(20.936)	(20.686)
Fourth quartile (high income)					
2020*Income decline by 10%	1700.959	3493.826	30.071	43.049***	10.676
	(1042.114)	(2195.255)	(22.802)	(13.061)	(8.041)
2020*Income decline by 20%	1093.836	1872.989	-15.350	30.365*	34.951**
	(872.002)	(1516.411)	(22.617)	(16.213)	(16.634)
2020*Income decline by more than 20%	897.561	1520.112	24.870	41.350	10.143
	(843.089)	(1533.163)	(37.455)	(25.666)	(12.159)
2021*Income decline by 10%	-208.879	-691.168	21.065	-15.697	7.421
	(1093.886)	(2274.282)	(26.264)	(10.438)	(8.028)
2021*Income decline by 20%	198.911	357.666	-38.614	6.351	15.458
	(929.658)	(1591.491)	(29.666)	(16.317)	(16.767)
2021*Income decline by more than 20%	484.829	788.868	80.350	2.146	33.094
	(947.592)	(1735.255)	(66.487)	(20.359)	(21.739)

Standard errors in parentheses. Robust standard errors. *p < 0.10, ** p < 0.05, *** p < 0.010.
Note: Each regression includes year effects and household controls such as household size; number of children (0–5 years); household head sex, age, marital status, and education level; electricity outage; mean annual temperature; and urban–rural. Standard errors are clustered at the level of the household.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

Figure 2 summarizes the above results. The results are partly consistent with the energy ladder hypothesis, which shows the hierarchical relationship between economic status of households and energy sources: the higher the economic status or income, the greater the preference for more expensive and cleaner fuels (Heltberg 2005). Our findings confirm this effect in households that experienced income decline, though the higher income group increased consumption of biomass, which is considered a dirty fuel. Also, households in the second quartile group increased coal consumption. These findings suggest that income shock creates incentives for households to use dirty fuel and may raise concerns regarding a reversal of the clean energy transition process.

Figure 2: Impact of Income Decline on Energy Consumption



Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

5. CONCLUSION AND POLICY IMPLICATIONS

This paper has examined the impact of income decline in the post-COVID-19 period on household energy consumption in the Kyrgyz Republic. The research was based on panel data from the household survey for 2019–2022. For the empirical analysis, the DiD approach was applied based on unmatched and matched samples.

Empirical findings in general showed that households with income decline during the first year of the pandemic increased usage of biomass. This finding is in line with the general expectation that falling income may cause households to rely more heavily on less costly fuels. Also, the empirical results indicate heterogeneity by income group. Households in the lowest income group that faced income declines reduced total energy consumption, which suggests a potential challenge of energy poverty owing to income shock. The results confirm that higher income corresponds with the adoption of cleaner fuels. However, higher-income households that experienced income decline demonstrated increased use of dirty fuel too. These findings highlight the potential challenge that income shock impacts energy consumption patterns even of households with a higher income and may stagnate the transition to clean fuel.

The low-income group with income decline experiences a reduction in energy consumption. Consuming less energy than is required to enhance welfare in the long term may have negative consequences for health, human capital development and labor productivity. Special government efforts to support low-income groups in their energy consumption during periods of high energy needs, such as in the winter, are necessary to avoid the negative effects of energy poverty. This direction is becoming more important in the context of the practice of increasing electricity prices since 2023 in the Kyrgyz Republic.

Though this study did not cover the topic of influence of electricity tariffs on energy consumption, further studies on how these changes affect energy transition is important for sustainable development policy discussions in the Kyrgyz Republic. We could not show the significance of the quality of energy infrastructure (blackouts), which is most likely due to data over a short period of time (three years). A potential limitation of this study is that it does not address potential heterogeneity from unobservable differences. Although CEM is an efficient approach in terms of the construction of the treatment and control groups, it is based only on observable characteristics of households, whereas time-varying unobserved heterogeneous characteristics may still impact results. However, the full solution of this issue is non-trivial in a panel data setting.

APPENDIX

Table A1: Difference of Mean Values of Outcome Variables Across Treated and Control Groups

	Control	Treated	Difference
Total energy consumption	1,472.98	1,228.37	244.61
Coal	1,063.02	843.99	219.03
Electricity	648.48	640.38	8.10
Biomass	77.45	68.16	9.29
Gas	96.98	100.37	-3.40
N	3,272	1,213	

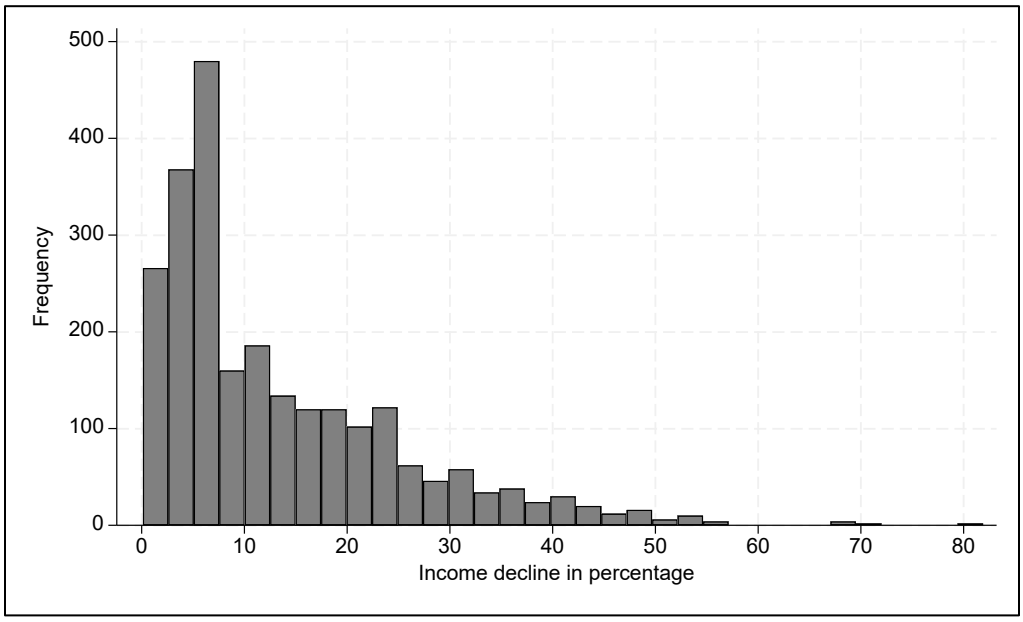
*p < 0.10, ** p < 0.05, *** p < 0.010.
Note: Values are for pre-treatment 2019 year.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

Table A2: L_1 Statistics Before and After Coarsened Exact Matching

	Before CEM		After CEM	
	L_1	Mean	L_1	mean
Sex of household head	0.007	-0.007	0.000	0.000
Age of household head	0.094	2.655	0.059	0.029
Marital status of household head	0.002	-0.002	0.000	0.000
Education of household head				
Primary and below	0.005	0.005	0.000	0.000
Secondary general	0.017	-0.017	0.000	0.000
Technical education	0.018	-0.018	0.000	0.000
Tertiary education	0.030	0.030	0.000	0.000
Household size	0.065	-0.268	0.011	0.004
Number of children (0–5 years)	0.057	-0.103	0.000	0.000
Electricity outage (1=never to 3=several times in a week)	0.007	-0.003	0.000	0.000
Urban	0.015	0.015	0.000	0.000
Multivariate L_1	0.632		0.395	
N	4,485		2,376	

CEM = Coarsened Exact Matching.
Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

Figure A1: Distribution of households by income decline magnitude



Source: Authors' calculations based on the Kyrgyz Integrated Household Survey data.

REFERENCES

Abdeen, Ahmed, Farzam Kharvari, William O'Brien, and Burak Gunay. 2021. "The Impact of the COVID-19 on Households' Hourly Electricity Consumption in Canada." *Energy and Buildings* 111280. https://doi.org/10.1016/j.enbuild.2021.111280

Ai, Hongshan, Tenglong Zhong, and Zhengqing Zhou. 2022. "The Real Economic Costs of COVID-19: Insights from Electricity Consumption Data in Hunan Province, China." *Energy Economics* 105747. https://doi.org/10.1016/j.eneco.2021.105747

Alem, Yonas, Abebe Beyene, Gunnar Köhlin, and Alemu Mekonnen. 2016. "Modeling Household Cooking Fuel Choice: A Panel Multinomial Logit Approach." *Energy Economics* 9: 129-137.

Andersen, Frits, Philipp Gunkel, Henrik Jacobsen, and Lena Kitzing. 2021. "Residential Electricity Consumption and Household Characteristics: An Econometric Analysis of Danish Smart-Meter Data." *Energy Economics* 100: 105341. https://doi.org/10.1016/j.eneco.2021.105341

Azhgaliyeva, Dina, Ranjeeta Mishra, and Kamalbek Karymshakov. 2021. "Household Energy Consumption Behaviors During the Covid-19 Pandemic in Mongolia." Working Paper. Tokyo: ADBI.

Azhgaliyeva, Dina, Ranjeeta Mishra, Kamalbek Karymshakov, Aiymgul Kerimray, Zhanna Kapsalyamova Z. 2021. "What Determines Coal Consumption for Residential Heating in Kazakhstan and the Kyrgyz Republic?" *Australasian Journal of Environmental Management* 28 (4): 410–432.

Azhgaliyeva, Dina, Wataru Kodama, and Hans Holzhacker. 2025. "Does awareness and prioritization of environment and health matter for household fuel choice? Empirical evidence from Central Asia." *Energy Research and Social Science*. https://doi.org/10.1016/j.erss.2024.103898

Azhgaliyeva, Dina, Hans Holzhacker, Dil Rahut, and James Correia. 2024. "Empowered Women Prioritize the Environmental and Health Impacts of Fuel Choice: Empirical Evidence from Central Asia." Working Paper. Tokyo: ADBI.

Balabanyan, Ani, Kathrin Hofer, Joshua Finn, and Denzel Hankinson. 2015. "Keeping Warm: Urban Heating Options in the Kyrgyz Republic—Summary Report." Washington, DC: World Bank.

Balest, Jessica, and Agnieszka Stawinoga. 2022. “Social Practices and Energy Use at Home During the First Italian Lockdown Due to Covid-19.” *Sustainable Cities and Society* 78: 103536. https://doi.org/10.1016/j.scs.2021.103536

Chen, Jiahui, Hua Liao, and Tong Zhang. 2024. “Empowering Women Substantially Accelerates the Household Clean Energy Transition in China.” *Energy Policy* 187: 114048. https://doi.org/10.1016/j.enpol.2024.114048

David, Guy, Evan Rawley, and Daniel Polsky. 2013. “Integration and Task Allocation: Evidence from Patient Care.” *Journal of Economics and Management Strategy* 22 (3). https://doi.org/10.1111/jems.12023

Do, Truong Lam, Trung Thanh Nguyen, and Ulrike Grote. 2019. “Livestock Production, Rural Poverty, and Perceived Shocks: Evidence from Panel Data for Vietnam.” *The Journal of Development Studies* 55 (1): 99–119.

Filippín, Celina, Silvana Flores Larsen, and Victoria Mercado. 2011. “Winter Energy Behaviour in Multi-Family Block Buildings in a Temperate-Cold Climate in Argentina.” *Renewable and Sustainable Energy Reviews* 15: 1. https://doi.org/10.1016/j.rser.2010.09.038

Gupta, Manavi, and Avinash Kishore. 2022. “Unemployment and Household Spending in Rural and Urban India: Evidence from Panel Data.” *The Journal of Development Studies* 58 (3): 545–560.

Han, Xiao, and Chu Wei. 2021. “Household Energy Consumption: State of the Art, Research Gaps, and Future Prospects.” *Environment, Development and Sustainability* 23 (8): 12479–12504.

Hasan, Syed, and Pallab Mozumder. 2017. “Income and Energy Use in Bangladesh: A Household Level Analysis.” *Energy Economics* 65: 115–126.

Hashemi, Majid. 2022. “How Would Residential Electricity Consumers Respond to Reductions in Power Outages?” *Energy for Sustainable Development* 69: 1–10.

Heltberg, Rasmus. 2005. “Factors Determining Household Fuel Choice in Guatemala.” *Environment and Development Economics* 10 (3): 337–361.

Henry, Matthew, Morgan Bazilian, Chris Markuson. 2020. “Just Transitions: Histories and Futures in a Post-COVID World.” *Energy Research and Social Science* 68: 101668. https://doi.org/10.1016/j.erss.2020.101668

Iacus, Stefano, Gary King, and Guiseppe Porro. 2011. “Multivariate Matching Methods That Are Monotonic Imbalance Bounding.” *Journal of the American Statistical Association* 106 (493): 345–361.

Iacus, Stefano, Gary King, and Guiseppe Porro. 2012. “Causal Inference without Balance Checking: Coarsened Exact Matching.” *Political Analysis* 20 (1): 1–24.

International Energy Agency (IEA). *Kyrgyzstan 2022: Energy Sector Review*. Washington, DC: IEA.

Kapsalyamova, Zhanna, Ranjeeta Mishra, Aiymgul Kerimray, Kamalbek Karymshakov, and Dina Azhgaliyeva. 2021. “Why Energy Access Is Not Enough for Choosing Clean Cooking Fuels? Evidence from the Multinomial Logit Model.” *Journal of Environmental Management* 290: 112539. https://doi.org/10.1016/j.jenvman.2021.112539

Kawka, Emily, and Kristen Cetin. 2021. “Impacts of COVID-19 on Residential Building Energy Use and Performance.” *Building and Environment* 205: 108200. https://doi.org/10.1016/j.buildenv.2021.108200

Khalil, Mohamad Ali, and Mahmudur Rahman Fatmi. 2022. “How Residential Energy Consumption Has Changed Due to COVID-19 Pandemic? An Agent-Based Model.” *Sustainable Cities and Society* 81: 103832. https://doi.org/10.1016/j.scs.2022.103832

Li, Danny, Liu Yang, and Joseph Lam. 2012. “Impact of Climate Change on Energy Use in the Built Environment in Different Climate Zones—A Review.” *Energy* 42: 103–112.

Li, Houjian, Andi Cao, Martinson Twumasi, Hongzhen Zhang, Shunbin Zhong, and Lili Guo. 2023. “Do Female Cadres Improve Clean Energy Accessibility in Villages? Evidence from Rural China.” *Energy Economics* 126: 106928. https://doi.org/10.1016/j.eneco.2023.106928

Meles, Tensay. 2020. “Impact of Power Outages on Households in Developing Countries: Evidence from Ethiopia.” *Energy Economics* 91: 104882. https://doi.org/10.1016/j.eneco.2020.104882

Mendez Ramos, Fabien, and Jaime Lara. 2022. “COVID-19 and Poverty Vulnerability.” Brookings Commentary, 18 May. www.brookings.edu/articles/covid-19-and-poverty-vulnerability/

Mustapa, Siti, Rajah Rasiah, Amar Jaaffar, Aisyah Abu Bakar, and Zeittey Kaman. 2021. “Implications of COVID-19 Pandemic for Energy-Use and Energy Saving Household Electrical Appliances Consumption Behaviour in Malaysia.” *Energy Strategy Reviews* 38: 100765. https://doi.org/10.1016/j.esr.2021.100765

National Statistical Committee of the Kyrgyz Republic (NSCKR). 2021. “Methodology for Calculating the Fuel and Energy Balance (TEB).” www.stat.kg/en/statistics/download/methodology/141/

Ngui, Dianah, John Mutua, Hellen Osiolo, and Eric Aligula. 2011. “Household Energy Demand in Kenya: An Application of the Linear Approximate Almost Ideal Demand System (LA-AIDS).” *Energy Policy* 39 (11): 7084–7094.

Novianto, Didit, Mochammad Koerniawan, Munawir Munawir, and Dian Sekartaji. 2022. “Impact of Lifestyle Changes on Home Energy Consumption During Pandemic COVID-19 in Indonesia.” *Sustainable Cities and Society* 83: 103930. https://doi.org/10.1016/j.scs.2022.103930

Pelenur, Marcos and Heather Cruickshank. 2012. “Closing the Energy Efficiency Gap: A Study Linking Demographics with Barriers to Adopting Energy Efficiency Measures in the Home.” *Energy* 47 (1): 348–357.

Rouleau, Jean, and Louis Gosselin. 2021. “Impacts of the COVID-19 Lockdown on Energy Consumption in a Canadian Social Housing Building.” *Applied Energy* 287: 116565. https://doi.org/10.1016/j.apenergy.2021.116565

Ryan, Andrew, Evangelos Kontopantelis, Ariel Linden, and James Burgess. 2019. “Now Trending: Coping with Non-Parallel Trends in Difference-In-Differences Analysis.” *Statistical Methods in Medical Research* 28 (12): 3697–3711.

Sarkodie, Samuel, and Philip Adom. 2018. “Determinants of Energy Consumption in Kenya: A NIPALS Approach.” *Energy* 159: 696–705.

Shimizutani, S, and Yamada E. 2021. “Resilience Against the Pandemic: The Impact of COVID-19 on Migration and Household Welfare in Tajikistan.” *PLOS ONE* 16 (9): e0257469. https://doi.org/10.1371/journal.pone.0257469

Sulaimanova, Burulcha, Dina Azhgaliyeva, and Hans Holzhacker. 2024. “House Insulation: Perceived Needs and Willingness in Central Asia.” Working Paper. Tokyo: ADBI.

Surahman, Usep, Djoni Hartono, Erni Setyowati, and Aldissain Jurizat. 2022. “Investigation on Household Energy Consumption of Urban Residential Buildings in Major Cities of Indonesia During COVID-19 Pandemic.” *Energy and Buildings* 261: 111956. https://doi.org/10.1016/j.enbuild.2022.111956

Tian, Jinfang, Longguang Yu, Rui Xue, Shan Zhuang, and Yuli Shan. 2022. “Global Low-Carbon Energy Transition in the Post-COVID-19 Era.” *Applied Energy* 307: 118205. https://doi.org/10.1016/j.apenergy.2021.118205

United Nations Industrial Development Organization (UNIDO). 2019. “Health and Pollution Action Plan. Kyrgyz Republic.” www.unido.org/sites/default/files/files/2019-10/KyrgyzstanHPAP.English.pdf

Van Zoest, Vera, Karl Lindberg, Fouad El Gohary, and Cajsa Bartusch. 2023. “Evaluating the Effects of the COVID-19 Pandemic on Electricity Consumption Patterns in the Residential, Public, Commercial and Industrial Sectors in Sweden.” *Energy and AI* 14: 100298. https://doi.org/10.1016/j.egyai.2023.100298

Yan, Aqian, Xiaofeng Luo, Junbiao Zhang, and Lin Tang. 2024. “Does Internet Use Promote Clean Energy Use for Cooking by Women-Headed Rural Households in China?” *Utilities Policy* 86: 101703. https://doi.org/10.1016/j.jup.2023.101703

Zapata-Webborn, Ellen, Eoghan McKenna, Martin Pullinger, Callum Cheshire, Harry Masters, Alex Whittaker, Jessica Few, Simon Elam, and Tadj Oreszczyn. 2023. “The Impact of COVID-19 on Household Energy Consumption in England and Wales from April 2020 to March 2022.” *Energy and Buildings* 297: 113428. https://doi.org/10.1016/j.enbuild.2023.113428

Zheng, Xinye, Chu Wei, Ping Qin, Jin Guo, Yihua Yu, Feng Song, and Zhanming Chen. 2014. “Characteristics of Residential Energy Consumption in China: Findings from a Household Survey.” *Energy Policy* 75: 126–135.

Zou, Baolin, and Biliang Luo. 2019. “Rural Household Energy Consumption Characteristics and Determinants in China.” *Energy* 182: 814–823.

Assessing the Impact of Income Decline on Household Clean Fuel Choice

Evidence from the Kyrgyz Republic

This paper analyzes the impact of income decline during the COVID-19 pandemic on energy consumption in the Kyrgyz Republic. Using household survey data for the period 2019–2021, results show that households in the lowest (first quartile) income group reacted to an income decline by consuming less coal, whereas those in the second quartile income group increased coal consumption. Spending more time at home during the pandemic in the context of a falling income may have created incentives to switch to a cheaper fuel.

About the Asian Development Bank

ADB is a leading multilateral development bank supporting sustainable, inclusive, and resilient growth across Asia and the Pacific. Working with its members and partners to solve complex challenges together, ADB harnesses innovative financial tools and strategic partnerships to transform lives, build quality infrastructure, and safeguard our planet. Founded in 1966, ADB is owned by 69 members—49 from the region.

ADB

ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org