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Increasing Block Tariff Electricity Pricing and the Propensity to Purchase Dirty Fuels: Empirical Evidence from a Natural Experiment

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Abstract:

This paper investigates the relationship between the increasing-block-tariffs (IBT) for electricity, and the propensity of households to purchase dirty fuels. We combine RLMS-HSE, a panel household data, with the introduction of the IBT schemes for residential electricity in three experimental regions of Russia to analyze this relationship. Using differences-in-differences empirical specifications we find that the propensity to purchase dirty fuels has increased in the regions where the IBT schemes were introduced. Depending on the specification, and the type of household we find that the size of the increase varies from more than 3-percentage points to about 15-percentage points. This accounts for a roughly 70% increase, and a 90% increase respectively compared to the similar households in the regions that did not implement IBT pricing schemes for residential electricity. The empirical evidence from this paper suggests that the environmental benefits that result from the implementation of the IBT pricing schemes may be overstated if the possible negative environmental impacts of switching to more affordable, but hazardous energy sources by the population as a response to the tariff-shifts are not taken into account by the policymakers.

JEL: Q41, Q48, L98, L94

Keywords: residential electricity pricing; increasing-block-tariffs; CO2 emissions; dirty fuels; transition economy; natural experiment

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1. Introduction

The supply of energy below the market value is usually implemented by the countries to ensure that all people (both poor and non-poor) have access to affordable energy sources. This type of pricing strategy, however, is not without its drawbacks. Adequate pricing of energy needs to allow for cost recovery to minimize the power sector's negative macroeconomic, fiscal, environmental, and social impacts. More precisely, low energy prices usually result in such negative consequences as the deterioration of energy infrastructure due to a lack of investments in this sector, low quality of the supplied energy, and rolling blackouts (Huenteler et al., 2017).

Moreover, there is ample evidence suggesting that underpricing of electricity may lead to its overconsumption, which in turn leads to increased levels of environmental impacts, such as groundwater over-extraction, and greenhouse gas (GHG) emissions (Monari, 2002; IEA et al., 2010; Badiani et al., 2012; Rentschler and Bazilian, 2016). Underpricing also may remove incentives for investing in energy efficiency and renewable energy (Rentschler and Bazilian, 2016).

Many developing and transition countries recognize these issues and try to implement more liberal market approaches for pricing energy. The energy pricing that enables the cost recovery, however, can also lead to a number of undesired outcomes like deforestation, and high income-shocks, especially among the poor and vulnerable segments of the population (Kaiser, 2000; Lampietti et al., 2007; Gassmann, 2014; Gassmann and Tsukada, 2014; Krauss, 2016).

Designing and implementing efficient energy subsidy programs, however, also proved to be a challenging task due to the various transaction costs (Valentová et al., 2018a), and the significant differences between the expected, CO2 emission reduction and ex-post, real attained reduction partly due to the methodical issues, and the behavioral factors (Valentová et al., 2018b).

Some authors suggest that the effects of the increase in energy prices on the poor could be mitigated by supplying some quantities of energy at a lower price (Freund and Wallich, 1997; Lampietti et al., 2007). This can be achieved essentially by implementing an increasing-block-tariffs (IBT) for the main energy sources, like gas, electricity, and the like. Implementing IBT pricing, also, however, can be complicated by consumer inattentiveness (Borenstein, 2009; Ito, 2014), and cognitive bias (Lin and Zhu, 2021; Liu and Lin, 2020) which in turn may decrease the effectiveness of the IBT policies.

In addition, there is ample evidence suggesting that in the face of various reforms (like the implementation of IBT) that raise the price of basic energy sources like gas, and electricity the population in the developing and transition economies may alter their energy consumption patterns towards cheaper, and dirtier alternatives like coal, kerosene, wood, and the like. This is particularly true in the post-Soviet countries in Eastern Europe, and Central Asia, where the region's cold climate and relatively low-income levels can influence the design of heating strategies of the population (Lampietti and Meyer, 2002).

Following the above arguments, this paper investigates how the propensity to purchase dirty fuels was affected by the IBT electricity pricing in Russia, one of the major exporters and consumers of world energy sources (IEA, 2021), and the world's fourth major polluting country ("bp Statistical Review of World Energy", 2021).

We employ the "Russian Longitudinal Monitoring Survey by Higher School of Economics (RLMS-HSE)", a household-level panel data, which among others also records whether the household has purchased some selected types[1] of dirty fuels during the last 30 days prior to the interview.

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[1] More specifically, firewood, coal, peat, or kerosene.

The IBT schemes were introduced in seven regions of Russia as an experiment in 2013. This was accomplished as an attempt to introduce a cross-subsidizing scheme, where households with relatively higher electricity consumption subsidize a part of the cost of supplying the electricity to the households that consume less electricity (Samofalova, 2014). Unlike, in many other countries, however, the consumption cut-offs of the higher-priced consumption blocks are household-specific, and are based, among others, on such factors as household size, whether the household is located in an urban or a rural area, and whether it receives any social benefits (Veretennikova, 2014).

In particular, following Turdaliev (2021a, 2021b), where the author, using the same data, shows that the introduction of the IBT pricing scheme resulted in the increased propensity to purchase major home electrical appliances, and Turdaliev (2021c) where the author shows that the consumers are aware of the prescribed households specific block-cut-offs, we show that the IBT pricing schemes also resulted in the increased purchase of dirty fuels in these regions. This indicates that the effects of the IBT pricing schemes in Russia are quite complex, and have both positive and negative environmental aspects.

The rest of the paper is structured as follows. Section 2 provides some background information on Russia and implemented IBT electricity pricing in the selected experimental regions. Section 3 introduces the data, and relevant descriptive statistics. Section 4 describes the empirical methodology, and variables used. Section 5 summarizes the results, and Section 6 concludes.

2. Country background and the Implementation of IBT

The Russian power sector was a state-run monopoly before 2003. However, after the start of the liberalization 20 independent power companies were created by 2008. This trend has been reversed soon after, however. As of 2012, the large transmission and distribution assets were reunited under a state-controlled, Russian Grids public joint-stock company

(PJSC). Today, power grids are largely operated by Russian Grids PJSC, which provides power to over 70% of the Russian population and to industrial facilities that account for over 60% of the Russian GDP (Josefson et al., 2017). The remaining electricity is provided by over 20, mostly regional-specific, smaller power companies (Josefson et al., 2017).

With a total capacity of 243 GW, Russia has the fourth-largest power grid in the world. Generation is accomplished mainly (about 67%) by thermal power plants, that are operated mainly on natural gas and coal. The remaining electricity generation is provided by hydroelectric power plants and nuclear energy (Sidorenko, 2011; Josefson et al., 2017). According to the survey by the Federal State Statistics Service (Rosstat for short), more than 70.6% of the households heat their homes via district heating networks[2], 21.9% via privately installed boilers operating throughout the whole dwelling, and 7.3% heat their homes via traditional stoves. These traditional stoves, in turn, operate almost entirely on wood (80%) or coal (19%) (Semikašev, 2008; Antonov, 2020).

Although the majority of the population heat their homes via district heating networks every tenth family in Russia suffers from insufficient heating of the dwelling during the wintertime (Antonov, 2020). Moreover, in recent surveys, the insufficient heating of the dwelling was reported as the fourth most important issue faced by homeowners and renters in Russia (Rosstat, 2021). Therefore, even when connected to the district heating networks, or privately installed boilers, many households tend to supplement their primary source of heating with additional heaters operating on solid fuels or electricity (Semikašev, 2008; Antonov, 2020). According to Rosstat (2021), every fourth family supplements their primary heating source with some additional source of heating, the majority of which (about 70%) operate on electricity (Semikašev, 2008; Antonov, 2020).

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[2] Usually in a form of hot water flowing through pipes supplied to installed radiators within the dwelling by the local boiler stations, or heat-and-power plants (Sorokina, 2019).

Electricity prices have been gradually liberalized, and about 80% of electricity is currently traded at unregulated market prices. However, the public still receives electricity at state-set prices, as the residential electricity prices are regulated by the Federal Monopoly Service (Josefson et al., 2017).

Residential electricity prices in Russia vary considerably from region to region but are still largely based on a flat rate system. In a recent attempt to introduce an internal subsidy scheme in which the households consuming high amounts of energy subsidize part of the cost of the households consuming low amounts of energy, the federal government has introduced so-called social norms in seven pilot regions (hereinafter referred to as "experimental regions”) since September 2013 (Samofalova, 2014).

Households that consume within the prescribed social norm pay a lower unit price for electricity, while the households that consume beyond the prescribed social norm pay a higher unit price for each kWh consumed above the designated social norm. The prescribed social norms are calculated on a per capita basis and are different in each of the seven experimental regions. Social norms range from 50 kWh per capita in Vladimir Oblast to 190 kWh per capita in Orlov Oblast (Veretennikova, 2014). In some experimental regions, the calculation of social norms is also complicated by such factors as whether the household is located in rural or urban areas, whether the household receives any social benefits, and whether the electric stove is used as the main means of cooking (see, Table 1).

In practice, "social norms" work in the same way as some other countries' increasing-block-tariff (IBT) schemes: consumption below a specified level is priced at a lower unit price, while consumption above that level is priced at a higher price. Thus, in our case, all seven experimental regions have effectively implemented the two-block tariff system. As shown in Table 1, block cut-offs are determined by the characteristics of households and the dwellings they reside in.

The government initially planned to extend the social norms to all regions of Russia, but the implementation of this plan was suspended indefinitely for various reasons (Veretennikova, 2014; Antonov, 2018). The original plan called for nine pilot regions, but two of them (Primorsky Krai, and Lipetsk Oblast) opted out by September 2013. The officials of these regions argued that the calculation of social norms provided by the federal government was too vague and the calculation of social norms differed considerably between the regions even though some of these regions had nearly identical weather and socioeconomic conditions (Veretennikova, 2014).

This argument favors our estimation procedure as it indicates that the calculation of social norms was done quite exogenously. It is also important to note that out of the seven regions that have implemented social norms/IBT schemes, only three (Rostov Oblast, Krasnoyarsk Krai, and Nizhny Novgorod Oblast) are surveyed by RLMS-HSE. Table 1 summarizes the calculation of social norms (in kWh) in these three regions of Russia.

Region	***Rostov***			***Krasnoyarsk***			***Nizhny Novgorod***		
Household type	n=1	n=2	n=3+	n=1	n=2	n=3+	n=1	n=2	n=3+
Urban	96	156	156+40×(n-2)	110	150	75×n	85	100	100+50× (n-2)
rural	186	246	246+40× (n-2)						
urban + electric stove	186	242	156+40×(n-2) +43×n	220	300	150×n	85	100	100+50× (n-2)
rural + electric stove	276	332	246+40×(n-2) +43×n						
receiving social benefits	×1.5	×1.5	×1.5	×1.0	×1.0	×1.0	85	×1.5	×1.5

Table 1: The prescribed social norms for electricity consumption

Source: Regional electricity suppliers.[3] Note: "*n*" denotes the household size.

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[3] See, Old.donland.ru (2019); Ševcov (2018), and "Social norm" (2019).

In addition to a substantial variation in social norms, we also observe considerable differences in electricity tariffs across the regions. Figures 1-4 (available in the Appendix) show the historical monthly electricity tariff schedules for the three experimental regions and the average electricity tariff schedules for all control regions. [4]

[Figure 1]

[Figure 2]

[Figure 3]

[Figure 4]

Tariffs usually change once a year in all regions simultaneously. The tariffs vary considerably from region to region, mainly depending on the average income of the population and weather conditions. Tariffs also differ between the customers who do not have access to a district gas supply and those connected to the district gas networks. This is because households without a gas supply are usually forced to use an electric stove for cooking, which significantly increases the consumption of electricity. Thus, between 2010 and 2013, there are two different tariffs (flat tariff for households with an electric stove, and flat tariff for households without an electric stove) in three experimental regions, and four different tariffs (first and second-tier consumption for households with electric stoves, and first and second tier consumption for households without electric stoves) after the introduction of social norms in September of 2013.

There is a possibility that some households may have access to a district gas supply, but still prefer to have an electric stove in their homes. The proportion of these households, however, is quite small and accounts for less than 1% of our sample. We drop these households from the estimations to avoid any ambiguity.

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[4] Residential electricity tariffs were obtained from the Federal State Statistics Service of Russia.

The average first-tier electricity tariff for all surveyed regions increased from 235 rubles per 100 kWh in 2010 to 409 rubles per 100 kWh in 2019. Breaking down the historical tariff changes in the experimental regions, we can see that the first-tier electricity tariff has increased from 191 per 100 kWh in 2010 to 321 rubles per 100 kWh in 2019. In control regions, the first-tier tariff has increased from 240 rubles per 100kWh in 2010 to 418 rubles per 100 kWh in 2019.

Second-tier tariffs can only be observed in the three experimental regions since September of 2013. The average tariff for consumption in excess of the established social norm in the three experimental regions increased from 366 rubles per 100 kWh in 2013 to 512 rubles in 2019. The electricity tariff schedules for households with electric stoves in both control and experimental regions followed roughly the same pricing pattern but with a factor of approximately 0.7 due to higher base consumption resulting from a lack of access to a district gas supply.

3. Household data

This paper utilizes the Russia Longitudinal Monitoring Survey - Higher School of Economics (RLMS-HSE), a household panel survey data conducted jointly by the National Research University "Higher School of Economics" and OOO “Demoscope” together with Carolina Population Center, the University of North Carolina at Chapel Hill and the Institute of Sociology of the Federal Center of Theoretical and Applied Sociology of the Russian Academy of Sciences.[5]

RLMS-HSE is a series of nationally representative surveys designed to monitor the effects of Russian reforms on the health and economic welfare of households in the Russian Federation (Gerry & Papadopoulos, 2015). RLMS-HSE was first conducted in 1994 and is repeated yearly across 38 main regions of Russia (except for 1997, and 1999 when surveys

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[5] https://www.hse.ru/en/rlms.

were not conducted) up to this date. For this study, we are using ten waves of RLMS-HSE conducted between 2010 to 2019, the same period as in Turdaliev (2021a, 2021b), where the author investigates the impact of the introduction of the IBT for residential electricity on the propensity to purchase major electrical appliances. We chose to conduct the analysis starting from 2010 to avoid the possible impacts of the 2008-2009 global financial crisis on our results.

Our dependent variable is a binary indicator for the purchase of some selected category of dirty fuels by the household within the last 30 days prior to the interview. More specifically the household's head is asked whether:

"The family has purchased firewood, coal, peat, or kerosene in the last 30 days?" (hse.ru, "wave 19 Household Data File", 2010, pp. 208).

The four aforementioned types of fuels are considered to be the most widely used dirty fuels by households (WHO, 2015), and thus can be used as a proxy for the overall purchase of dirty fuels. Unfortunately, we do not observe which types of dirty fuels (out of the listed ones) were purchased. Neither do we observe in what quantities these fuels were purchased. Therefore, our results can be interpreted as an indication of a change in the overall propensity (frequency) of purchase of these four aforementioned types of dirty fuels by the households.

Below, we present the descriptive statistics for the households for the three experimental regions available in RLMS-HSE, and the 35 control regions. In our particular case, the experimental regions comprise 4768 households, and the control regions comprise 48272 households.[6] Thus about 10% of the households are located in the experimental regions.

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[6] Excluding households observed only once during the survey period (singleton values) (about 15%), renters (about 10%), and households that report installing electric cooking stove, while also being connected to the district gas supply (about 1%).

Table 2: Characteristics of the Dwelling

Variables	**Control regions:** Percentage of the Sample or Mean (standard deviation in parentheses)	**Experimental regions:** Percentage of the Sample or Mean (standard deviation in parentheses)	**Difference in Means:** Standard error in parentheses
***Type of dwelling*:**			
Single-family home	27.1%	21.8%	5.3%***
Apartment in a multi-family building	72.6%	77.9%	-5.3%***
Size of the dwelling in square meters	56.33 (23.65)	54.63 (20.30)	1.699*** (0.325)
Urban	67.2%	94.0%	-26.8%***
Has an Electric stove	19.7%	37.4%	-17.7%***
Electricity consumption [7](September)	179.11 (109.80)	185.88 (98.39)	-6.77*** (1.946)
***Has central delivery of*:**			
Gas	70.1%	52.2%	17.9%***
Heating	70.3%	77.4%	-7.2%***
Hot water	65.0%	75.0%	-10%***
Cold Water	88.1%	91.9%	-3.8%***

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

From Table 2 we can see that there are some major differences between experimental and control regions. In particular, the most striking difference is in the level of urbanization. Urbanization is much higher in the experimental regions, 94% vs 67.2%. The level of urbanization is in turn reflected in other variables of interest as well. For instance, we can see that the percentage of households with electric stoves is also higher in the experimental regions, with a difference of 17.7 percentage points. The electricity consumption for September is also about 4% higher in the experimental regions.

In terms of the connection to the main utilities, we can also observe that the central delivery of hot and cold water are 10 percentage points, and 3.8 percentage points respectively higher in the experimental regions.

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[7] The data for electricity consumption is available up to 2016.

It also should be noted that unlike the almost universal connection to electricity networks, in Russia gas connection is not universal. Many major cities and regions of Russia, including the Krasnoyarsk Krai (which is one of the experimental IBT regions under the study), do not have a central delivery of natural gas (Piterkina, 2021). In our particular study sample, the rate of connection to the district gas networks is 70.1% in the control regions and 52.2% in the experimental regions.

In addition, as described in Section 2, most of the buildings in Russia are connected to the district heating networks and are heated centrally (Sorokina, 2019). In our particular sample, more than 70% of the households are connected to the district heating networks, with 7 percentage points more centrally heated households in the experimental regions.

Other characteristics of the dwelling, described in Table 2, are quite similar across the regions. The majority of the households reside in multi-family apartments, both in the experimental (77.9%) and the control (72.6%) regions. The remaining households reside in single-family dwellings. The average size of the dwelling is about 55 square meters across all regions.

Table 3: Household's Socioeconomics

Variables	**Control regions:** Percentage of the Sample or Mean (standard deviation in parentheses)	**Experimental regions:** Percentage of the Sample or Mean (standard deviation in parentheses)	**Difference in Means:** Standard error in parentheses
Household size	2.743 (1.49)	2.825 (1.42)	-0.083*** (0.021)
Household monthly income (RU)	65190.51 (57276	65484.42 (45529)	-293.91 (775.07)
Receiving subsidies for utilities	29.23%	28.1%	1.13%**
Receiving discounts for utilities	17.8%	18.6%	-0.8%*
Have Debt for Utilities	7.6%	7.1%	0.5%
Education:			
Secondary	33.4%	29%	4.4%***
Professional-technical	23.6%	24.8%	-1.2%*
Higher education (BSc, MSc, DiS)	24.5%	26.7%	-2.2%***

Other	18.2%	19%	-0.8%

$^{*} p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$

Turning to the socio-economic characteristics of the households in Table 3, we can see that, here as well, some differences across the groups can be observed. First of all, there are some noticeable differences in the educational profile. More people in the experimental regions have obtained higher education, with a difference of 2.2 percentage points across the groups.

Professional-technical education is also more prevalent in the experimental regions, with a difference of 1.2 percentage points. The major differences in the urbanization and the educational profile are not reflected in the households' incomes, however. The average monthly household income (adjusted for the 2019 rubles) is about 65,000 rubles both in the experimental, and control regions. The household size is also identical, with about three individuals in the household on average.

We can also see that the share of the households receiving discounts for the utilities is almost identical across the groups (17.8% vs 18.6%). In the context of Russia, discounts for the utilities are received only by a certain segment of the population who are eligible for them including but not limited to, war veterans, disabled people, and large families with children. They are usually given in a form of reduced payments for the utilities typically ranging from 30% to 50% of the total utility bill. The discounts are granted for the lifetime, or until the youngest child from a large family turns 16 (or 18 depending on the region) (see, Necova, 2019; and "Benefits for paying for housing and communal services," 2019).

The share of the households receiving subsidies for the utilities is also quite similar, where almost 30% of all households across both types of regions are receiving some sort of subsidies. Subsidies contrary to the discounts are given for a short-term period, usually for six months, after which the individual has to reapply if they want to receive subsidies in the future. The eligibility for receiving a subsidy is determined by the share of the total utility payments compared to the total income received by the household. Unlike the discounts, the subsidy is given in a form of a cash-back payment (Necova, 2019; “Benefits for paying for housing and communal services,” 2019).

4. Empirical Methodology

To estimate the effect of the introduction of the IBT electricity pricing on the purchase of dirty fuels by households this paper utilizes standard difference-in-differences (DD) empirical specification (see, for instance, Angrist and Pischke, 2008). Our empirical model can be represented by Equation 1 below:

$$PurchDF_{it} = a_i + \tau_t + \boldsymbol{X}_{it}b_1 + ln\boldsymbol{W}_{it}b_2 + ln\boldsymbol{S}_{it}b_3 + b_4(treatment \times post) + \varepsilon_{it} \quad (1)$$

In particular, Equation 1 estimates the effects of the introduction of IBT pricing of electricity on the propensity to purchase dirty fuels (*PurchDF)* in the context of DD.

The variables on the right-hand side (RHS) consist of the time-varying vector ***(X)*** of household characteristics, such as total household income (in 2019 rubles), and household size. The vector ***(S)*** stands for the amount (in 2019 rubles) of any subsidies or discounts received by the household, while vector ***(W)*** controls for the weather conditions of the region.[8]

The b_i are the parameters to be estimated. The parameter of interest is the parameter on the interaction term $(treatment \times post)$, which stands for the interaction of the experimental regions with its observation in the post-treatment period. This parameter is represented by b_4, which is the conventional DD parameter, that researcher tries to estimate.

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[8] In particular, we control for the log of heating degree days, log of precipitation, log of wind speed, and log of humidity levels across all 38 regions under the study. The weather data was provided by www.meteoblue.com.

The terms a_i and τ_t stand for the household fixed effects, and the year fixed effects respectively.

We estimate the equation above using Ordinary Least Squares (OLS) with Fixed effects to take full advantage of the panel nature of the data. As indicated in Section 3 our dependent variable in Equation 1 is a binary choice variable, taking a value of one ($PurchDF_{it} = 1$) if the household has purchased firewood, coal, peat, or kerosene within the last 30 days, and taking a value of zero ($PurchDF_{it} = 0$) otherwise.

The binary nature of the dependent variable means that in the context of OLS, Equation 1 is estimated via a Linear Probability Model (LPM). The LPM model has several advantages compared to its nonlinear counterparts like Probit or Logit models. More specifically LPM is more convenient, computationally tractable, and may have less bias than other nonlinear model alternatives, especially in the context of panel data (see, for instance, Friedman & Schady, 2012).

Although LPM is often viewed as a better alternative to its nonlinear counterparts in the context of panel data, any regression results estimated by LPM can suffer from two potential problems that are specific to LPM.

The first problem is that OLS suffers from heteroscedasticity when estimated from a binary response variable. However, this problem is easily solved by using standard heteroscedasticity robust error estimates.

The second problem is more complex and arises since LPM estimates are not limited to the unit interval. Thus, one can get probability estimates that are greater than one or less than zero. However, if the main purpose is to estimate the partial effect on the probability of response averaged over the distribution of the independent variables, then, as Wooldridge (2002) argues, the fact that some predicted values are outside the unit interval may not be so important (p. 455). In addition, LPM is expected to be unbiased and consistent if no, or very few, predicted probabilities lie outside the unit interval (Horrace & Oaxaca, 2006). We show in the "Results" section that in our case the estimated probabilities lying outside the unit interval are virtually nonexistent.

In addition, as evident from the descriptive statistics of the selected sample we can observe substantial differences in the observed characteristics between experimental and control regions. In this case, the researcher usually employs various statistical matching techniques to reduce the imbalance in the covariates between the observations in the experimental and control groups. We use the coarsened exact matching (cem) technique to account for the relatively small experimental group and the differences in covariates across the groups. The cem procedure is a relatively new development in the matching literature. However, compared to other matching techniques, the cem procedure has several advantages. In particular, it requires fewer assumptions and has more attractive statistical properties than many of its counterparts (Iacus et al., 2012).

We match the households on the household size, size of the dwelling (in square meters), the type of the dwelling (single dwelling, or multi-apartment), location (urban, or rural), household income, whether the household is connected to the district hot water delivery, district gas supply, and whether the dwelling is connected to the district heating networks.

In addition, we will also estimate Equation 1 only for the subset of the households that are not connected to the district heating networks, as the effects of the increase in the prices of the main energy sources like gas, and electricity may be more pronounced among these households that use these energy sources as their main source of heating (Krauss, 2016).

5. Results

First, we are examining the outcome variables for the experimental and control groups over time. From Table 4, and Table 5 we can observe that the propensity to purchase dirty fuels was higher in the experimental regions even before the introduction of the IBT schemes.

However, the difference between the regions becomes even more pronounced after the introduction of the IBT in 2013, both for the full sample of the households, as well as for the subset of households with no district heating.

We can see that the difference across both types of regions is positive and highly statistically significant. Examining the full sample of the households we can see that the estimated unconditional increase in the propensity to purchase dirty fuels due to the introduction of the IBT is almost two percentage points.

Looking at the same estimates for the households without a connection to the district heating networks, we can see that the unconditional DD estimate shows a 6.5 percentage points increase.

Table 4: Unconditional DD Estimates for Propensity to Purchase Dirty Fuels-

Full Sample

	Pre-period	Post-period	Difference (post-pre)
T=1	0.0436486	0.0586044	0.0149558
T=0	0.0337594	0.0298852	-0.0038742
Diff-in-Diff			0.01883*** (0.0062926)

Robust standard error in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 5: Unconditional DD Estimates for Propensity to Purchase Dirty Fuels-

Households with no District Heating

	Pre-period	Post-period	Difference (post-pre)
T=1	0.1694118	0.2204724	0.0510606
T=0	0.1039295	0.0900689	-0.0138606
Diff-in-Diff			0.0649212*** (0.023426)

Robust standard error in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Having observed some considerable, and highly statistically significant effects of the IBT on the purchase of dirty fuels, we next test the hypothesis in the context of the DD framework including time-varying household characteristics, along with household, and year fixed effects to take full advantage of a panel nature of the data.

Table 6 reports the Fixed effects regression estimates. Column 1 presents the FE estimates for the full sample of the households, while Column 2 presents the same estimates, but with a cem procedure prior. Columns 3 and 4 repeat the same estimation procedure for the subsample of households without connection to the district heating networks.

Table 6: Fixed effects regression (*Dependent variable: Purchase of dirty fuels)*

	(1) FullSample	(2) FullSample_ matched	(3) NoDist.Heating	(4) NoDist.Heating_ matched
DD	0.039***	0.031***	0.152***	0.135***
	(0.009)	(0.009)	(0.036)	(0.038)
(log)ElectPrice	-0.047**	-0.038*	-0.168***	-0.153**
	(0.020)	(0.021)	(0.060)	(0.069)
(log)Income	0.005**	0.004	0.017**	0.023*
	(0.002)	(0.003)	(0.008)	(0.013)
(log)Subsidies	0.001**	0.001***	0.002*	0.005***
	(0.000)	(0.000)	(0.001)	(0.002)
(log)Discounts	0.000	0.000	0.000	-0.000
	(0.000)	(0.000)	(0.001)	(0.002)
HHsize	0.000	-0.000	-0.007	-0.011
	(0.002)	(0.002)	(0.005)	(0.009)
year dummies:				
2010 *(base)*				
2011	-0.006*	-0.008*	-0.016	-0.030
	(0.004)	(0.004)	(0.012)	(0.020)
2012	-0.008**	-0.008*	-0.028**	-0.043**
	(0.004)	(0.004)	(0.012)	(0.020)
2013	-0.008**	-0.007	-0.025*	-0.037
	(0.004)	(0.005)	(0.014)	(0.023)
2014	-0.008**	-0.004	-0.024*	-0.020
	(0.004)	(0.004)	(0.013)	(0.022)
2015	-0.011**	-0.006	-0.033**	-0.032
	(0.004)	(0.005)	(0.015)	(0.024)
2016	-0.010***	-0.006	-0.032**	-0.035
	(0.004)	(0.005)	(0.013)	(0.022)
2017	-0.013***	-0.007	-0.044***	-0.038
	(0.004)	(0.005)	(0.014)	(0.023)
2018	-0.019***	-0.014**	-0.064***	-0.066***
	(0.005)	(0.006)	(0.015)	(0.025)
2019	-0.021***	-0.018***	-0.071***	-0.082***
	(0.006)	(0.006)	(0.017)	(0.027)
Weather controls	*yes*	*yes*	*yes*	*yes*
HH Fixed effects	*yes*	*yes*	*yes*	*yes*

N of Predicted values $\notin [0,1]$	0	0	54	5
N	53040	42142	15566	8499
F	2.264	2.081	2.499	2.037
p	0.001	0.004	0.000	0.005

Robust standard error in parentheses. $^{*} p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$

The matching estimator performs reasonably well in our specification. We start by examining the overall balance of the covariates between households in the experimental and control regions. As the measure of imbalance of the covariates between the groups, the cem uses the overall comprehensive measure L1, introduced by Iacus et al., (2008). It is based on the difference between the multidimensional histogram of the covariates across the two groups and is given by:

$$L_1(f,g) = \frac{1}{2}\sum_{l_1 \dots l_k} | f_{l_1 \dots l_k} - g_{l_1 \dots l_k} | \qquad (2)$$

Where $f_{l_1 \dots l_k}$ and $g_{l_1 \dots l_k}$ are the k-dimensional relative frequencies for the treated and control regions respectively obtained from the cross-tabulation of the coarsened covariates. First, we run L1 distance statistics on the unmatched data, and then use it as a comparison point (baseline reference) for the matched data. It should be also noted that the absolute values of the L1 statistics mean less than comparisons between the matching solutions. In this sense, the L1 statistics work for imbalance as R-squared works for the model fit (see Iacus et al., 2012 for details). If the L1 statistic of the matched data is closer to zero than its unmatched counterpart, then we can argue that after the matching procedure, the balance of covariates between the groups has improved.

In our case, the multivariate L1 distance statistic for unmatched data is 0.75, while for matched data, it is equal to 0.68, showing some improvement in the balance of covariates between the groups.

Out of the total of 53040 observations, the cem procedure pruned 10896 observations from the control group and 2 observations from the experimental group. Therefore, we have a total of 37376 observations in the control group, and 4766 observations in the experimental group, after the matching procedure.

When restricting the sample to the households with no connection to the district heating networks the numbers decrease to 7065 observations (out of a total of 14581) in the control group, and 983 observations (out of a total of 985) in the experimental group.

We can also see that the number of predicted probabilities lying outside the unit interval is virtually nonexistent across all specifications, except for the specification used in Column 3 of Table 6 where the number is still very small, and comprise only less than half of the percent of all the predicted probabilities.

Across all specifications, we can see that the effect of IBT (represented by the coefficient on DD in Table 6) on the propensity to purchase dirty fuels is positive and statistically significant. Looking at Column 1 of the regression output we see that the IBT results, on average, in the 3.9 percentage points, or about 90% increase in the propensity to purchase dirty fuels within the full sample of the households. The estimates of the LPM combined with the cem technique prior, results in a slightly smaller coefficient, indicating an increase of around 70%. Both estimates, however, are statistically significant at 1%.

Restricting the sample to the households which do not have access to the district heating, shows that the propensity to purchase dirty fuels has increased by more than 15-percentage points (or almost a 90% increase), and to more than 13-percentage points increase (or about 80% increase) in case of a prior cem application. As in the case of a full sample, the estimates for the households without district heating are statistically significant at 1%.

The coefficient on the level of the electricity price (as opposed to its structure estimated by the coefficient on DD) is negative and statistically significant across all specifications. The negative effect of the level of electricity price may be explained by the fact that households living in the areas with the higher electricity prices may have developed some long-term solutions towards their energy needs that are more independent from the dirty fuels (Lampietti et al., 2007).

The coefficient on the per capita income elasticity is positive, and statistically significant across all specifications. The estimates also show that purchase of dirty fuels is rather inelastic towards income. The income elasticity varies from 0.12[9] for the full sample of the households to 0.68 when restricting the sample to the households without district heating. This indicates that dirty fuels are a normal good in Russia, and are income-inelastic as, for example, some other energy sources like electricity (Turdaliev, 2021c).

The household size proved to be a statistically insignificant determinant of investment in dirty fuels across all of our model specifications. The monetary value of discounts (in 2019 rubles) for the utilities is also a statistically insignificant determinant of the investment in dirty fuels.

The monetary value of the subsidies (in 2019 rubles) for the utilities, on the other hand, has a statistically significant and positive association with the purchase of dirty fuels. The estimated elasticity of subsidies varies from 0.03, in the case of a full sample, to 0.15 in the case of households that are not connected to district heating. The positive and statistically significant effect of subsidies may be explained by the fact that, unlike discounts, the receipt of the subsidies is conditional on the ratio of overall spending on the utilities and the total income of the household. Thus, the households receiving subsidies must be the ones spending the higher share of their income on the utilities and thus are more prone to complement their energy needs with various dirty fuels.

6. Conclusion and Policy Implications

To ensure access to affordable energy sources developing and transition countries often supply energy at below the market prices. However, this may lead to a number of negative

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[9] The elasticity in lin-log specification is obtained by: $b \times (1/Y)$, where b is the regression coefficient and Y is the mean value of dependent variable.

outcomes like energy-intensive consumption and overconsumption of energy, which in turn leads to negative environmental impacts.

Literature often suggests supplying small amounts of energy at a lower price (Freund and Wallich, 1997; Lampietti et al., 2007), in order to minimize possible negative social impacts of the increased energy prices on the poor and negative environmental impacts resulting from the heavily subsidized energy pricing. This policy proposition can be achieved by implementing an increasing-block-tariffs (IBT) for the main energy sources.

In this paper, we combine RLMS-HSE, a panel household data, with the introduction of the IBT schemes for residential electricity in three experimental regions of Russia to analyze the effects of the IBT schemes on the propensity of households to purchase dirty fuels. To the best of our knowledge, this is the first paper to conduct an empirical test of the impacts of IBT on the purchase of dirty fuels in the context of household panel data combined with a variation in energy prices resulting from a natural experiment.

Using differences-in-differences empirical specifications we find that the propensity to purchase dirty fuels has increased in the regions where the IBT schemes were introduced. Depending on the specification, and the type of household we find that the size of the increase varies from more than 3-percentage points in the case of households connected to the district heating networks to about 15-percentage points among the households that do not have access to the district heating networks. This accounts for a roughly 70% increase, and a 90% increase respectively compared to the similar households in the regions that did not implement the IBT pricing.

The empirical evidence from this paper suggests that the related environmental benefits that result from the implementation of the IBT pricing schemes (for example, in terms of the increased propensity to invest in energy efficiency, as reported in Turdaliev, (2021a, 2021b)) may be overstated if the possible negative environmental impacts resulting from switching to more affordable, but hazardous energy sources by the population as a response to the tariff-shifts are not taken into account by the policymakers.

It should be noted, however, that from the data, we can only observe whether the household has purchased some of the listed dirty fuels (firewood, coal, peat, or kerosene) within the last 30-day prior to the interview. We do not observe which types of dirty fuels (out of the listed ones) were purchased. Neither do we observe in what quantities these fuels were purchased. Therefore, our results should be interpreted only as a possible indication of the change in the overall usage of dirty fuels following the adaptation of the IBT pricing for the residential electricity in the experimental regions.

Nevertheless, a substantially large increase in the propensity to purchase dirty fuels in the experimental regions is a result worth documenting. Possible quantitative evaluation of the increase in the negative environmental impacts of the dirty fuels in these experimental regions we leave as an avenue for future research, once more detailed data is available.

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Appendix

Figure-1

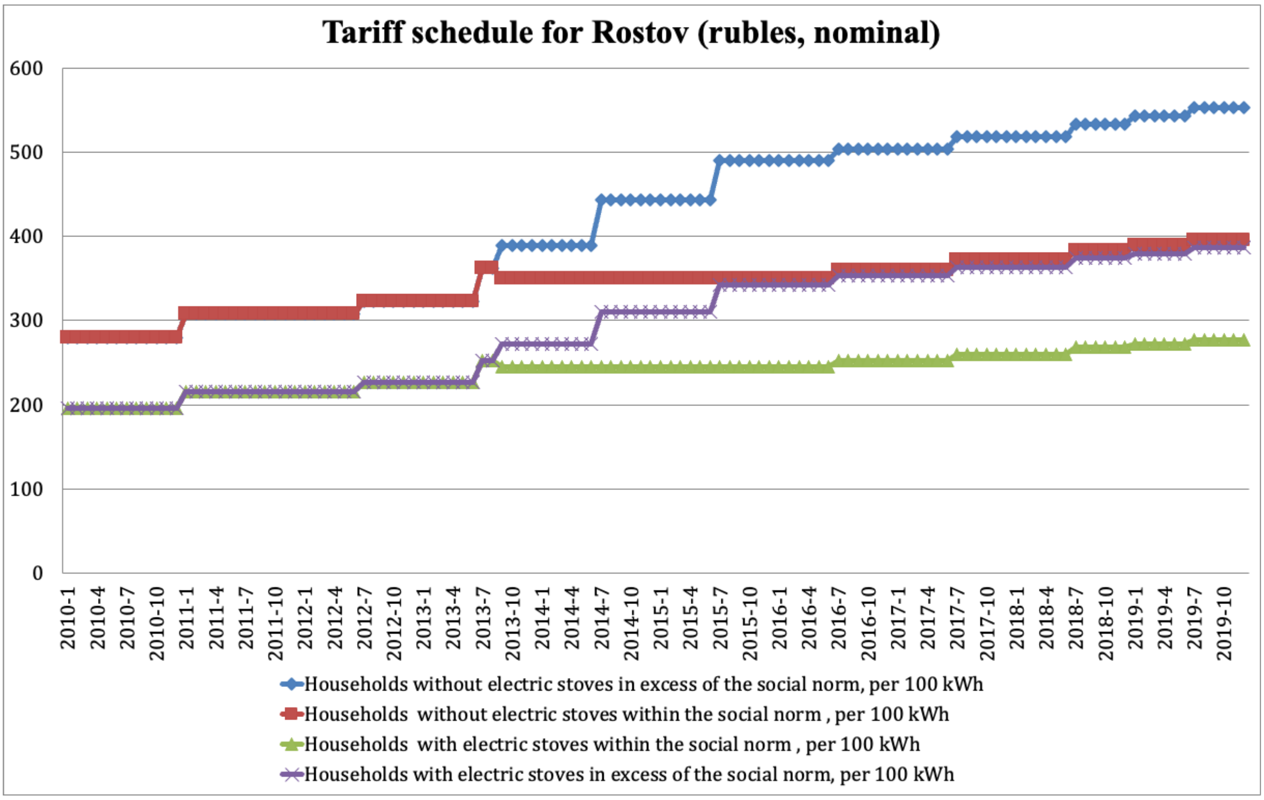


Figure-2

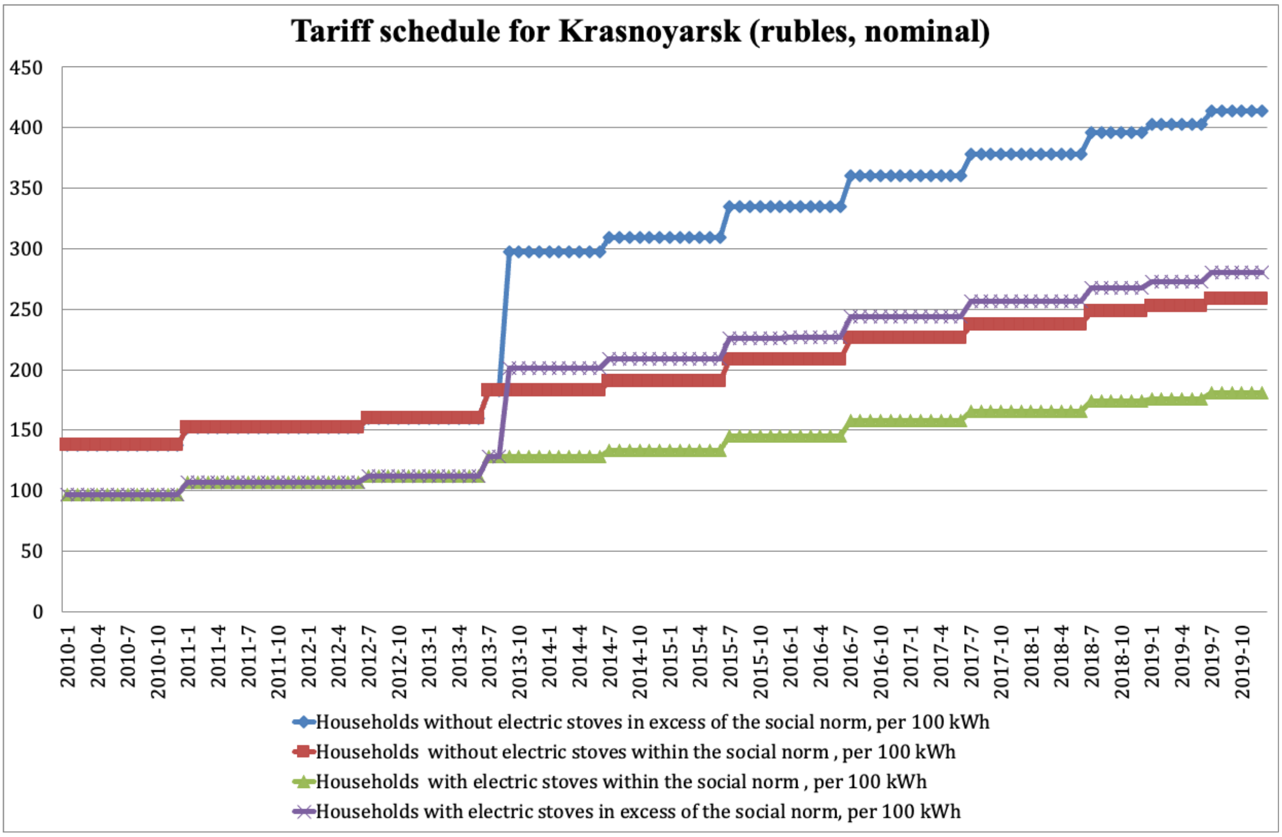


Figure-3

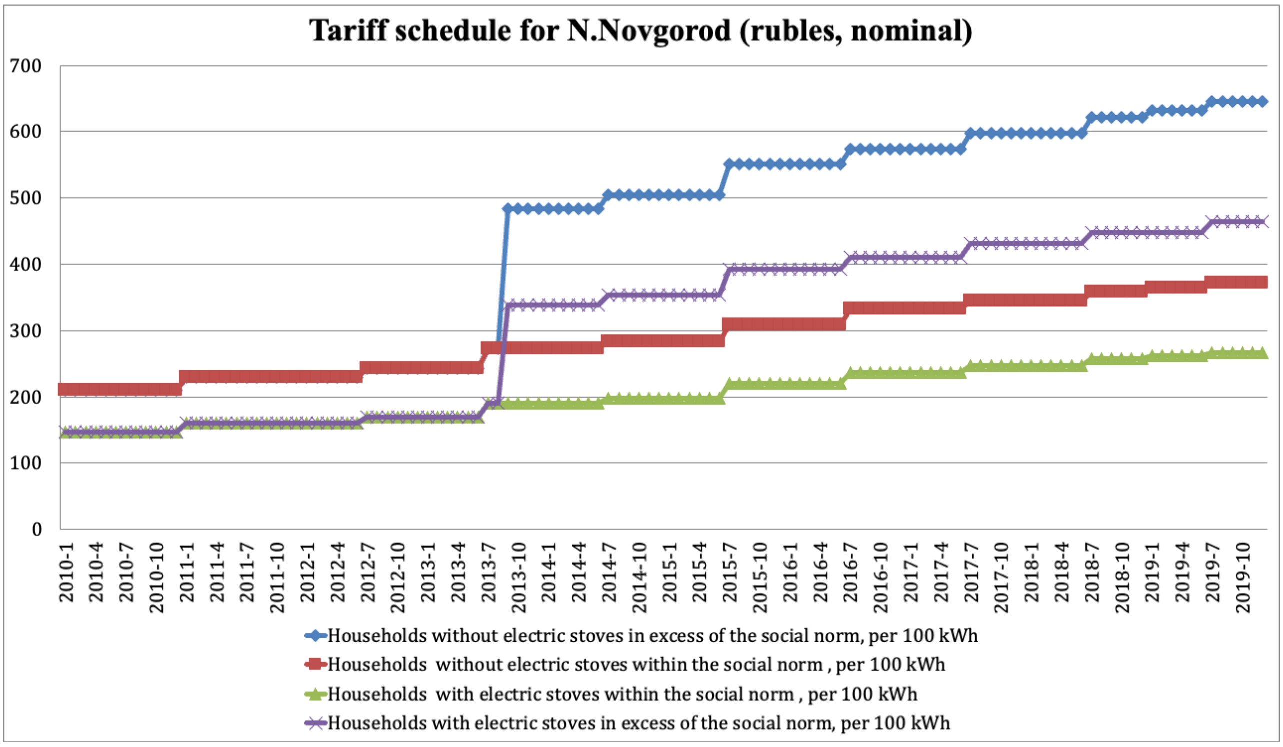
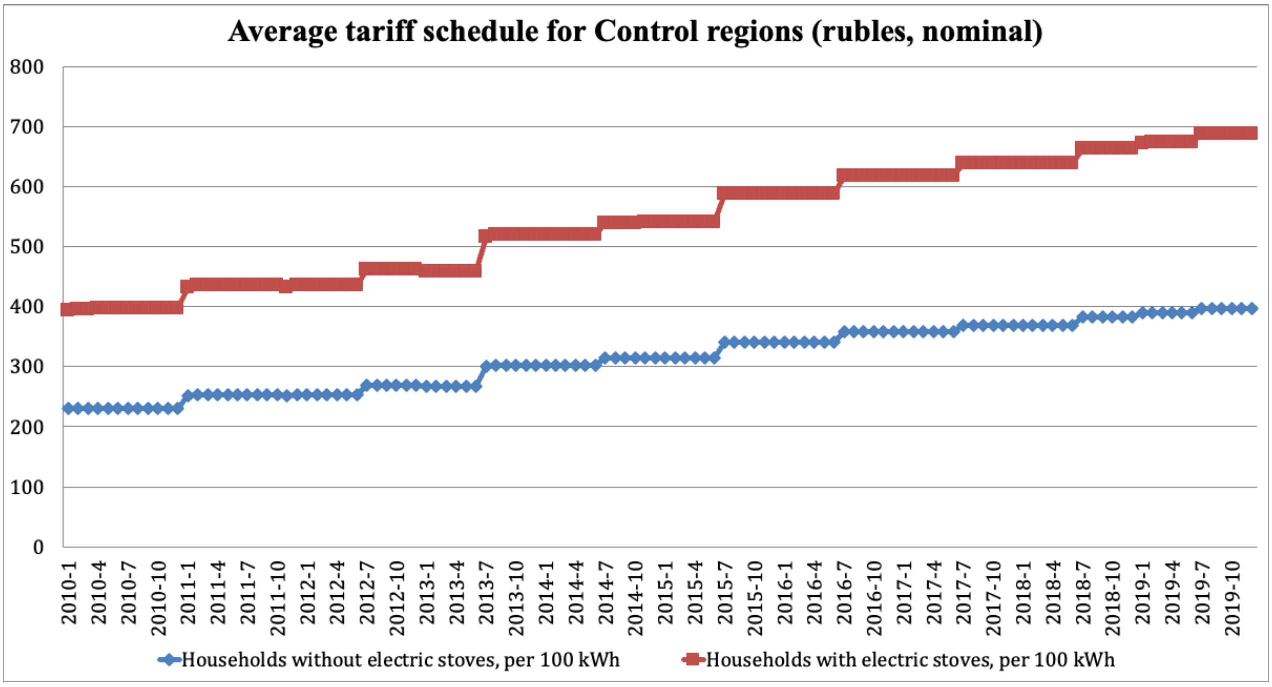

Tariff schedule for N.Novgorod (rubles, nominal)
700
600
500
400
300
200
100
0
2010-1
2010-4
2010-7
2010-10
2011-1
2011-4
2011-7
2011-10
2012-1
2012-4
2012-7
2012-10
2013-1
2013-4
2013-7
2013-10
2014-1
2014-4
2014-7
2014-10
2015-1
2015-4
2015-7
2015-10
2016-1
2016-4
2016-7
2016-10
2017-1
2017-4
2017-7
2017-10
2018-1
2018-4
2018-7
2018-10
2019-1
2019-4
2019-7
2019-10
Households without electric stoves in excess of the social norm, per 100 kWh
Households without electric stoves within the social norm , per 100 kWh
Households with electric stoves within the social norm , per 100 kWh
Households with electric stoves in excess of the social norm, per 100 kWh

Figure-4


Average tariff schedule for Control regions (rubles, nominal)
800
700
600
500
400
300
200
100
0
2010-1
2010-4
2010-7
2010-10
2011-1
2011-4
2011-7
2011-10
2012-1
2012-4
2012-7
2012-10
2013-1
2013-4
2013-7
2013-10
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2017-1
2017-4
2017-7
2017-10
2018-1
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2018-7
2018-10
2019-1
2019-4
2019-7
2019-10
Households without electric stoves, per 100 kWh
Households with electric stoves, per 100 kWh

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