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Increasing Block Rate Electricity Pricing and Propensity to Purchase Electric Appliances: Evidence from a Natural Experiment

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INCREASING BLOCK RATE ELECTRICITY PRICING AND PROPENSITY TO PURCHASE ELECTRIC APPLIANCES: EVIDENCE FROM A NATURAL EXPERIMENT

Salim Turdaliev

IES Working Paper 27/2021

$$\frac{1}{(m-1)!} p^{m-1} (1-p)^{n-m} = p \sum_{\ell=0}^{n-1} \frac{\ell+1}{n} \frac{(n-1)!}{(n-1-\ell)! \ell!} p^{\ell} (1-p)^{n-1-\ell} = p \frac{n-1}{n} \sum_{\ell=0}^{n-1} \left[\frac{\ell}{n-1} + \frac{1}{n-1} \right] \frac{(n-1)!}{(n-1-\ell)! \ell!} p^{\ell} (1-p)^{n-1-\ell} = p^2 \frac{n-1}{n} +$$

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Increasing Block Rate Electricity Pricing and Propensity to Purchase Electric Appliances: Evidence from a Natural Experiment

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Abstract:

This paper provides empirical evidence on the relationship between increasing-block-rate (IBR) pricing of electricity and the propensity of households to buy major electric appliances. I use variation from a natural experiment in Russia that introduced IBR pricing for residential electricity in a number of experimental regions in 2013. The study employs household-level panel data which records, among others, whether the household has purchased any major electric appliances during the last 3 months. Using difference-in-differences specification I show that in the regions with IBR pricing the purchase of major electric appliances has increased by more than 25 percent (2 percentage points). The findings suggest that price-based energy policies may be an effective tool in shaping the behavior of households.

JEL: Q3, Q4, D1, D9

Keywords: appliances, increasing-block-rate tariff, electricity prices, energy efficiency gap

1. Introduction

Characterizing how consumers respond to energy prices is an important avenue of research for the last 50 years. In particular, the extent to which the consumers invest in energy-efficient appliances following the changes in energy pricing policies has important implications in carbon mitigating policies.

The so-called energy efficiency paradox states that people underinvest in energy-efficient technologies which can provide a low-cost solution to reducing CO₂ emissions, and even provide positive returns in a form of reduced energy bills (see, for instance, Allcott & Greenstone, 2012; Gillingham & Palmer, 2014).

The studies analyzing the decision to purchase energy-efficient appliances gained heightened interest after the concerns regarding the environmental deterioration started to grow in the second half of the 20th century. Investing in energy-efficient home appliances is one of the main channels through which investment in energy efficiency may occur. One of the first to study and model the consumer decision to purchase and use of energy durables was Hausman (1979). In his seminal paper, he concludes that households value, but discount the future energy savings substantially when making the purchase decision. Gately (1980) provides a similar analysis on a sample of refrigerators and arrives at a similar conclusion.

Dubin & McFadden (1984) analyzed the purchasing behavior of heating systems using a sample of 3249 households and confirm the findings of previous studies. They also find that consumers value but substantially discount, and thus undervalue the future energy costs provided by energy-efficient appliances.

Contrary to the previous findings Rapson (2014) documents that the consumers are more forward-looking than thought previously and take into account the future savings realized by

the energy-efficient appliances. Moreover, the author concludes that consumer demand for electric appliances (air conditions in particular) is more elastic for energy efficiency than the up-front price of the durable.

Houde & Aldy (2014) investigate the impact of the 2009 energy efficiency rebates program in the US. They find that rebates do not enforce consumers to increase investment into energy-efficient appliances. The authors explain this result by a high proportion of “free riders”, consumers who would have upgraded to energy-efficient appliance even without the rebates program, and an “income effect”, meaning that the rebates received by the consumers induced them to buy bigger and more energy-intensive units of appliances, a phenomenon closely related to the rebound effect.

Taking into consideration the supply side of the production decision Cohen and colleagues (2015) show that the existing energy efficiency gap in the home appliances market is not only due to the consumer myopia but also due to the producers pricing less energy-efficient appliances more favorably. Moreover, the authors document that manufacturers change their product portfolio in response to the rising electricity prices. Authors conclude that shifting the attention towards the producers would help to achieve energy efficiency gains in the durables market.

Some authors also investigate whether the price of electricity and its structure affect a household’s decision to invest in energy-efficient technology. In particular, Jacobsen (2015) investigates whether the electricity prices affect the investment in energy-efficient appliances using state-year panel data on electricity prices and the proportion of sales of new appliances that involve high efficiency “Energy Star” models in the US. The collective set of results indicated that changes in electricity prices are not positively associated with changes in the market share of Energy Star appliances. Similar to Jacobsen (2015), Borenstein (2007) finds

that the “time of use” (TOU) pricing schedule does not have any substantial effect on the household’s decision to install solar PVs.

In a closely related study Liang et al., (2020) investigate the relationship between the structure of the electricity tariff and investment in energy-efficient appliances and solar panels using household-level data in Phoenix, Arizona. In particular, authors find that the consumers who adopt the time-of-use (TOU) electricity pricing are 27-percent more likely to adopt solar panel installation, but not more likely to invest in energy-efficient air conditioning. Authors, however, also conclude that their results should be interpreted as correlations, and do not claim any causal relationship due to the lack of plausibly exogenous variation.

In my study, I combine the Russian Longitudinal Monitoring Survey (RLMS-HSE), a household-level panel data, with a variation in electricity tariff that results from a natural experiment in Russia to estimate the relationship between increasing-block-rate (IBR) pricing and the propensity of consumers to purchase electric appliances. I find that households that face IBR pricing are more than 25 percent (2 percentage points) more likely to purchase major electric appliances.

Although I do not observe any energy efficiency indicators for the appliances, taking into account the robust trend of newer appliances becoming more energy-efficient¹, it is possible to propose that consumers purchasing new electric appliances are also purchasing more energy-efficient appliances. Using this proposition, the results of this paper can potentially suggest that price-based energy policies are an effective tool not only in shaping the household's behavior but also in shaping the behavior towards higher energy efficiency, which is considered one of the lowest-cost opportunities for reducing carbon emissions.

¹ See for instance, Adams 2009; Perry, (2012)

To the best of my knowledge, this is the first study that combines household-level panel data, with variation resulting from a natural experiment to estimate the relationship between IBR pricing and the propensity of households to purchase electric appliances. Therefore, this paper can potentially close an important gap in the literature.

The rest of the paper is structured as follows. In the following section, I present some background information on the electricity market in Russia and describe the natural experiment. Section 3 presents the data and the description of the selected sample. Section 4 outlines the methodology of the study, while Section 5 summarizes the results. Section 6 concludes.

2. The Electricity Market, and the Natural experiment

Until 2003, the entire power market was regulated by RAO UES, a fully integrated state monopoly. The RAO UES, however, was unbundled into 20 independent power companies by 2008, after the power sector began to liberalize. However, there has been a resurgence in power asset acquisition in recent years. Russian Grids (PJSC), a state-controlled public joint-stock company, consolidated the vast transmission and distribution assets. Russian Grids owns and operates most power grids nowadays, with transmission and distribution of power to over 70% of the Russian population and industrial facilities accounting for over 60% of Russian GDP ² (Josefson et al., 2017).

² With a gross capacity of 243GW, Russia has the world's fourth-largest electric power grid. Thermal power plants, which operate almost entirely on natural gas and coal, produce the majority of the electricity (about 67 percent). Hydroelectric power plants (20 percent) and nuclear power plants (12 percent) provide the remaining 30%. (Sidorenko, 2011; Josefson et al., 2017).

Electricity pricing has been increasingly liberalized, and about 80% of electric power is now traded on the open market at non-regulated market rates. However, in the near future, the public is likely to continue to purchase electric power at state-regulated rates, including residential tariffs set by the Federal Antimonopoly Service (ibid).

In Russia, residential electricity pricing is still largely based on a flat tariff system, though with significant regional variance in price per kilowatt. A recent effort to implement a cross-subsidizing system, in which households with higher electricity usage cross-subsidize households with lower electricity consumption, Russia began implementing a social norm for electricity use in several pilot regions in September of 2013, with plans to expand the social norm to all Russian regions by July 2014. Households that consume less than the prescribed social norm pay at a subsidized lower price, whereas households that consume more than the prescribed social norm pay at a higher market price.

The social norm for electricity consumption is based on household per capita electricity consumption and is different in each of Russia's seven experimental regions. The social norm varies from 50 kWh per capita in Vladimir oblast to 190 kWh per capita in Orlov oblast (Veretennikova, 2014).

The estimation of the social norm is also complicated (in some of the experimental regions) by such factors as the location of the household (whether it is in a rural or urban area), whether it has an installed electric stove, or the presence of individuals receiving benefits within the household (see table 1), among others.

Despite the complexities, the introduction of the social norm serves the same purpose as the increasing block rate tariff (IBR) in other countries. Consumption below a certain threshold is charged at a lower rate, whereas consumption above that threshold is charged at a higher rate. In these experimental regions thus, we deal with a two-block tariff regime.

Although the social norm was intended to be implemented across all Russian regions, it was postponed indefinitely due to a variety of factors (Veretennikova, 2014; Antonov, 2018). Furthermore, two of the proposed nine pilot regions (Primorsky Krai and Lipetsk oblast) opted out of the experiment before the social norms were piloted in seven regions in September 2013. The argument against implementation was that the federal government's methodology for calculating the social norm was somewhat ambiguous, as shown by significant variations in social norm across some of the experimental areas, even though some of them had virtually similar weather and socioeconomic conditions (Veretennikova, 2014). As a result, one might argue that the social norms were prescribed practically exogenously, favoring our estimation procedures.

Even though, the tariff based on a social norm was introduced overall in seven Russian regions, RLMS-HSE is not conducted in all of them. Out of the seven regions that took part in the experiment³, RLMS-HSE is conducted in *Rostov Oblast, Krasnoyarsk Krai, and Nizhny Novgorod Oblast*. Table-1 and Figure-1 below summarize the main information⁴ regarding the social norms (in Kwh) in these three regions of Russia.

Table 1: Prescribed social norm for electricity consumption

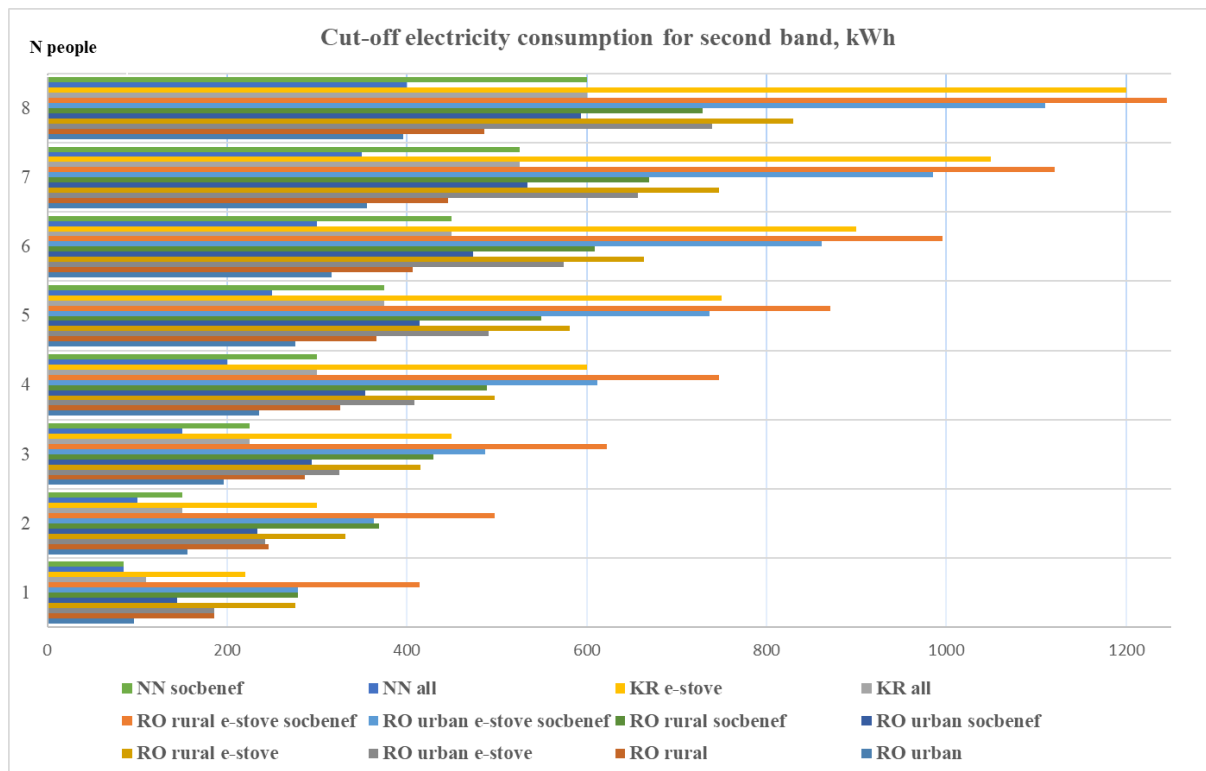
³In particular, these regions are Zabaykalsky Krai, Krasnoyarsk Krai, Vladimir Oblast, Nizhny Novgorod Oblast, Oryol Oblast, Rostov Oblast, and Samara Oblast.

⁴ The regional social norms for the residential electricity consumption were obtained from the regional energy suppliers. For more info see Old.donland.ru, (2019); Ševcov, (2018) “Social norm”, (2019).

Region	<i>Rostov</i>			<i>Krasnoyarsk</i>			<i>Nizhny Novgorod</i>		
	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	50+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	50+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

Source: Regional electricity providers. Note: "n" denotes the family size (i.e., the number of household members)

Figure 1



Note: Since in Nizhny Novgorod (NN) the second band cut-off differs only for households with social benefits, the graph depicts the second band cut-off for all households and those on social benefits. The same reasoning applies to Krasnoyarsk (KR), where the graph depicts cut-offs for households with electric stove, and all others. On the other hand, the calculation of the cut-off in Rostov (RO) is more complex and depends on such factors as location (rural or urban), electric stove, social benefits, and all possible combinations of these three factors.

3. Data

3.1 RLMS-HSE

RLMS-HSE is panel data and includes a wide set of questions on individual and family background characteristics. The majority of the interviews for RLMS-HSE are conducted during October and November.

The survey is conducted once a year in 38 major regions of Russia starting from 1994 and administers about 6000 households each year. However, in this paper, I use the data for the period of 2010 to 2019 to avoid any ambiguous results that can result from the 2008-2009 global financial crisis.

RLMS-HSE contains detailed information on the socio-economic characteristics of the household, and information on any form of subsidies and discounts on utilities received by the household.

In the Russian context, subsidies are short-term benefits given mostly on a basis of household income, in particular, the share of the total utility payments compared to the total income of the household. Any citizen with a permanent registration can apply for the subsidy. This subsidy is given for six months, and every six months it needs to be renewed. The subsidy is given in a form of a cash-back. The household pays the monthly utility bill as usual, and then the payment for the bill is partially returned to the household by the government in a form of

a cash-back (for more please see Necova, 2019, and “Benefits for paying for housing and communal services”, 2019).

Discounts, on the other hand, are given for the long term, and only certain segments of the population are eligible for them. These segments include but are not limited to war veterans, people with disabilities, and large families with children. The discounts are usually given in a form of reduced payment for the utility (a discount) and granted for a lifetime (in case of veterans, and disabled), or until the youngest child from a large family turns 16 or 18, depending on the region (ibid).

We can also identify whether the dwelling is in a multifamily building, or single-family building, whether it is connected to central delivery of electricity, gas, water, hot water, and heating. The size of the dwelling (in square meters) is divided into a total area and the area of the living rooms. Moreover, the respondents are asked to indicate whether they own the apartment they live in.

The questionnaire also asks to indicate all major electric appliances available within the household and to indicate whether the household has purchased any major electric appliance in the last 3 months. Unfortunately, the questionnaire does not ask to specify which particular appliance (if any) the household has purchased, and the energy efficiency rating of any of the given appliances.

This sampling approach of RLMS-HSE, combined with frequent (year) replenishment, ensures that the sample is cross-sectionally representative for each round. The average attrition rate is about 10-percent, and the overall attrition after 10 years is about 50 percent (see, Gerry & Papadopoulos, 2015 for more details).

3.2 Descriptive Statistics

For the selected years (2010-2019) we have a total of 53040 observations⁵. About 9 percent (4768) of which are households in treatment regions. Below I present the summary statistics for treatment and control households.

Table 2: Characteristics of the dwelling

	Control regions	Treatment regions
Variables	Percent of the Sample or Mean (standard deviation in parentheses)	Percent of the Sample or Mean (standard deviation in parentheses)
<i>Type of dwelling:</i>		
Single-family home	27.2%	21.8%
Apartment in multi-family building	72.7%	77.9%
Size of the dwelling in square meters	56.33 (23.65)	54.63 (20.30)
Urban	74.3%	94.0%
Has an Electric stove	19.7%	37.5%
Electricity consumption ⁶ (September)	179.83 (109.80)	186.27 (98.39)
<i>Has central delivery of:</i>		
Gas	70.1%	52.3%
Heating	70.3%	77.4%
Hot water	65.1%	75.0%
Cold Water	88.1%	92.0%

Table 3: Household's Socioeconomics

Average or percent of the sample (standard deviation in parentheses)	Control regions	Treatment regions
Household size	2.74 (1.49)	2.82 (1.42)
Household monthly income (RU)	65190 (57276)	65484 (45529)
Receiving discounts for utilities	28.3%	27.7.0%
Receiving subsidies for utilities	17.8%	18.6%
Have Debt for Utilities	7.6%	7.1%

⁵ Excluding all households which do not own the dwelling they reside in (e.g., renters). As in other post-Soviet countries home ownership in Russia is high. In our particular sample it is more than 91 percent.

⁶ The data for electricity consumption is available only up to 2016.

Education:		
Secondary	33.2%	29%
Professional-technical	23.9%	25.3%
High education (MSc, BSc, DiS)	24.7%	26.9%
Other	17.8%	18.2%

We can observe that the two samples are quite identical in terms of observed sample characteristics. The only major difference that we observe across the two samples is that the experimental dwellings are located in more urbanized areas, whereas the households in the control group are less urbanized. The urbanization level of the treatment group is 94-percent, whereas in the control group it is 74-percent.

This difference in urbanization in turn is reflected in several other variables of interest. Central delivery of gas is about 18 percent higher in the control group (52 percent vs 70 percent). This in turn is reflected in a higher percentage of installed electric stoves in treatment regions, 37 percent as opposed to 20 percent.

Other observed characteristics are fairly similar. The descriptive statistics show that majority of the families reside in multi-apartment buildings. The average size of the dwelling is about 55 m², while the average number of people residing in the dwellings is less than three individuals. Almost 30 percent of the households are receiving some benefits for utilities. The average household income is about 65,000 rubbles (adjusted for 2019).

Below I report the households' appliances decomposition 2010-2019.

Table 4: Major Appliances

	Control regions	Treatment regions
Appliance:	Percent of the Sample	
Air Conditioner	9.4%	10.1%
Dishwasher (automatic)	3.8%	2.6%
Refrigerator (no frost)	58.2%	61.4%
Washing machine (automatic)	79.3%	85.3%
Freezer	13.7%	22.1%
Microwave	66.8%	67.3%

In addition to the variation in social norms, we also observe a considerable variation in electricity tariffs across both experimental and control regions. I illustrate the monthly tariff schedule for 3 experimental regions and the average tariff schedule for 35 control regions for the period of 2010-2019 in the figures presented in the Appendix. The monthly electricity tariff data is obtained from a Russian statistical agency “Goskomstat”.

The tariff schedule in Russia changes usually once a year and simultaneously in all regions. It varies across regions substantially depending mostly on the average income of the population, and weather conditions. It also usually varies between residential customers who for various reasons do not have access to central gas supply and those who have central delivery of gas. This is because households without gas supply are forced to use electric stoves for cooking, which in turn increases their electricity consumption substantially. Thus, we deal with two (flat tariff for households with an electric stove, and flat tariff for those without) different tariffs between 2010 and 2013, and four tariffs after the introduction of social norm in 3 experimental regions (1st and 2nd tiers for households with electric stove, and without). Undoubtedly, we might have households that do have access to central gas supply, but still prefer to install electric stoves at home. However, out of about 21-percent of households with installed electric stoves, less than 1-percent reported both access to central gas delivery and installed electric stoves at home.

The average tariff for the first tier across all regions under the study has increased from about 235 rubles per 100 kWh in 2010 to 409 rubles in 2019. The first-tier tariff in experimental, and control regions followed roughly the same patterns, increasing from 191 rubles to 321 rubles and from 240 rubles to 418 rubles respectively during the same period.

Tariffs for the second tier can be observed only in three experimental regions under the study starting from September of 2013. The average tariff for the second-tier consumption

(consumption above prescribed social norm) in three experimental regions grew from 366 rubles per 100 kWh in 2013 to 512 rubles per 100 kWh in 2019.

Tariff schedules for the households with electric stoves both in control and experimental regions followed the identical pattern, with a factor of roughly 0.7.

4. Methodology

In this study I employ “difference in difference” estimation to evaluate the effect of increasing block pricing on the investment in electric appliances. The empirical model is estimated by the Equation 1.

$$IA_{it} = a_i + \tau_t + X_{it}b_1 + \ln P_{it}b_2 + \ln S_{it}b_3 + (treatment * post)b_4 + \varepsilon_{it} \quad (1)$$

On the RHS we have time-varying control variables, household, and year fixed effects. As we are estimating the investment in electric appliances in the context of natural experiment, we also should include variables indicating whether the region is a part of the experimental IBR tariff regime (*treatment*), whether the region is observed before or after the introduction of the IBR (*post*), and the interaction of these two variables (*treatment*post*). In the difference in difference (DID) context the coefficient of the interaction term is the DID estimator that the researcher tries to estimate.

However, because my model includes individual fixed effects, and the treatment is time-invariant, I do not include the main effect of treatment. Also, because I include time fixed effects including a dummy indicator for the post-intervention period is also redundant.

The term $\ln P$ stands for the log of the average residential price (in 2019 Russian rubles) for electricity. The price has both time and household subscripts to account for the price variability both across years and regions. Because the household’s electricity consumption in

RLMS-HSE is observed only for one month in a year (September), I use the average prices of electricity rather than the marginal prices. The use of average prices is justified not only by data limitations but also by recent empirical evidence that the consumers react to average prices rather than marginal ones (see, for instance, Borenstein, 2009; Ito, 2014).

$\ln S$ is a vector of the (log) amount (in 2019 Russian rubles) of any benefits (subsidies and discounts) for the utilities received by the household. X is a vector of control variables like income of the household (in 2019 Russian rubles), and the number of individuals residing in the household. The terms α_i and τ_t stand for household fixed effects, and year fixed effects (which among others also controls for the imposition of economic sanctions by the international community towards Russia in 2014) respectively.

Our dependent variable IA_{it} is a binary indicator for the purchase of any major electric appliance within a 3 month by household i in year t .

To be more precise the questionnaire asks respondents if the household has purchased any energy-intensive electric appliances during the last 3 months. The exact formulation of the question is as follows:

“Has your family bought in the last 3 months any household appliances like: refrigerator, washing machine, vacuum cleaner, sewing machine, iron, food processor, and the like?” (Hse.ru. “Wave 19 Household Data File”, 2010, pp. 205).

To avoid ambiguity, the questionnaire also asks if the household has recently purchased any non-major appliances. The exact formulation of the question is as follows:

“Has your family bought in the last 3 months any recreational appliances like: TV, tape recorder, video, musical instruments, computer, camera and the like?” (Hse.ru. “Wave 19 Household Data File”, 2010, pp. 205).

Thus, we can differentiate between the purchase of energy-intensive major appliances and other recreational non-major appliances.

Although I do not observe energy efficiency of the electric appliances purchased by the household, there are evidences that over a period of twenty to thirty years the average improvements in energy efficiency can be up to 200-percent for a refrigerator, 50-percent for a room air conditioner, 65-percent for a typical freezer, and up to 100-percent for cloth washing machines, and dishwashing machines (Adams 2009; Perry, 2012). Therefore, in this study, I assume that for selected home electric appliances newly purchased appliances result in improvements in energy efficiency.

When the researcher tries to estimate the price elasticity of electricity demand in case of non-linear tariffs, such as in the presence of block pricing schemes, both marginal and average prices are endogenous (see, Alberini et al., 2019). A well-accepted method for dealing with endogenous marginal (average) prices under non-linear price schedules when estimating the price elasticity of electricity demand (when the dependent variable is usually log of electricity consumption) is to instrument for (log) price with the (log) full tariff schedule (Mansur & Olmstead, 2012; Nieswiadomy & Molina, 1988).

In this case, however, I am not estimating the price elasticity of electricity demand, and the dependent variable used in this study is a binary indicator for the purchase of electric appliances. This in turn should not result in a correlation between the electricity price and the error term in Equation 1.

However, to minimize any endogeneity concerns I also run the model above with instrumenting for the log of average price for electricity by the full tariff schedule.

Additionally, I also combine the model above with coarsened exact matching estimator (cem). Applying matching to any particular estimator usually serves as a tool to reduce imbalance between treatment and control groups, so that the empirical distribution of the covariates is more similar across the groups. The cem estimator has several advantages over other matching techniques. It requires fewer assumptions, and possesses more attractive statistical properties (Iacus et al., 2012).

I match treatment and control groups on the various household characteristics. More specifically, I match on square footage of the dwelling, size of the household, its type (single family or multi apartment), location (urban, rural), household income, and whether the household is connected to the central delivery of hot water, and central heating.

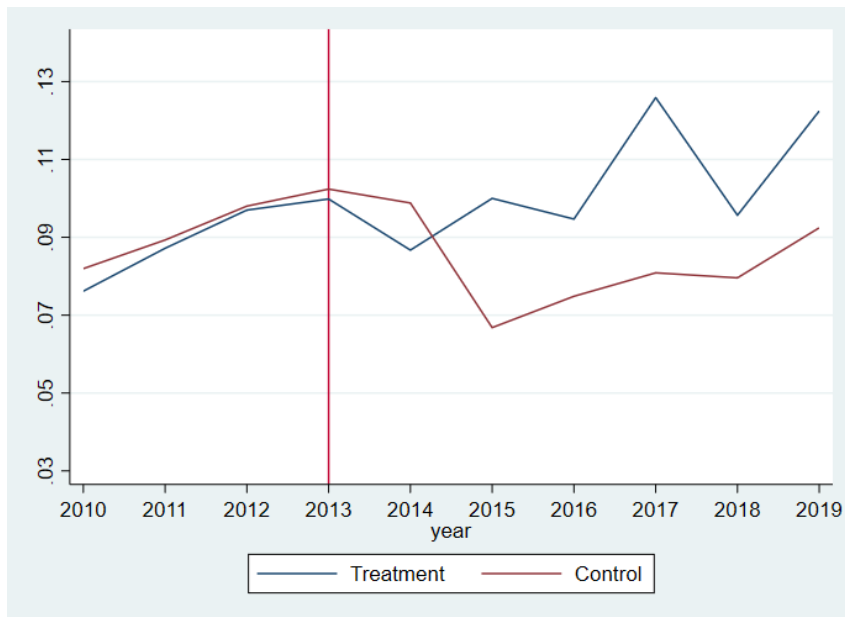
5. Results

5.1 Preliminary data checks

The key assumptions of the DID estimation technique are the “parallel trend”, and “common shocks” assumptions (Angrist & Pischke, 2008). In other words, absent the treatment itself, the treatment and control groups would have followed the same trends. That is, any omitted variables affect treatment and control in the same way. Usually, these assumptions are tested by examining the outcome variable over time for treatment and control groups.

Figure 2 below plots the propensity to purchase major electric appliances for control and treatment regions for the period of 2010-2019.

Figure 2: Propensity to purchase major appliances.



We can see that the purchase of major electric appliances was gradually increasing prior to 2014 in both treatment and control regions and went downward in 2014.

The drop of 2014 may potentially indicate that the households are forming “expectations” and hedging towards the uncertainty due to the conflict of Russia with Ukraine and postpone the purchase of electric durables. The more pronounced decline of 2015 observed in the control regions follows after the imposition of the economic sanctions by the international community in December of 2014 ⁷.

Taking into consideration that the decision to purchase home electric appliances is considered as a major investment by many households in Russia, we would anticipate that consumers will react to the treatment with some time lag.

Indeed, we observe that trends in treatment and control regions started to diverge in 2015 (two years after the introduction of IBR tariffs) when the propensity to purchase electric

⁷ The imposition of the sanctions also resulted in a severe devaluation of Russian ruble. By the January of 2015, the Russian ruble devalued by more than 100 percent against USD, and 60 percent against EUR compared to January of 2014 (tradingeconomics.com). Since in Russia most of the electronics is imported, this sharp devaluation increased the cost of all imported electric durables considerably.

appliances grew in treatment regions by 1.5 percentage points, whereas in control regions as mentioned above it actually fell by more than 3 percentage points.

Otherwise, the trends in treatment and control regions follow a similar trajectory, before 2014, and diverge only in 2015, and 2016. Afterward, the trends differ only in levels (which is crucial in DiD context), with the propensity to purchase major electric appliances in treatment regions being more than 2 percentage points higher, on average, during 2015-2019.

In table 5, I present unconditional diff-in-diff estimates for the propensity to purchase major electric appliances. Estimates show that the introduction of the IBR tariff in treatment regions was accompanied by about a 25 percent (2 percentage points) increase in the propensity to purchase major electric appliances.

Table 5: Unconditional DiD estimates for Propensity to purchase major appliances

	Pre-period	Post-period	Difference (post-pre)
T=1	0.0867	0.1034	0.0167
T=0	0.09	0.0854	-0.0046
Diff-in-Diff			0.0213** (0.0086)

Robust standard error in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.2 Placebo test

As a robustness check, I also repeat the analysis above for the variable indicating the purchase of other “non-major” appliances like “*TV, tape recorder, video, musical instruments, computer, camera and the like*” as outlined in the questionnaire⁸ of RLMS-HSE. If the increased propensity to purchase major electric appliances in treatment regions is indeed attributed to the introduction of the IBR tariff scheme, then we should not observe the

⁸ "Hse.ru. "Wave 19 Household Data File", 2010, pp. 205

same effect for the purchase of other “non-major” appliances in treatment regions as they are usually not that energy intensive.

Indeed, from the Figure-3, and Table 6 below, we cannot observe any significant relationship neither graphically nor in the DID specification. However, we can observe a sharp decline both in treatment and control regions of the propensity to purchase non-major electric appliances in 2015. Again, we can attribute this to the effect of the economic sanctions imposed by the international community at the end of 2014.

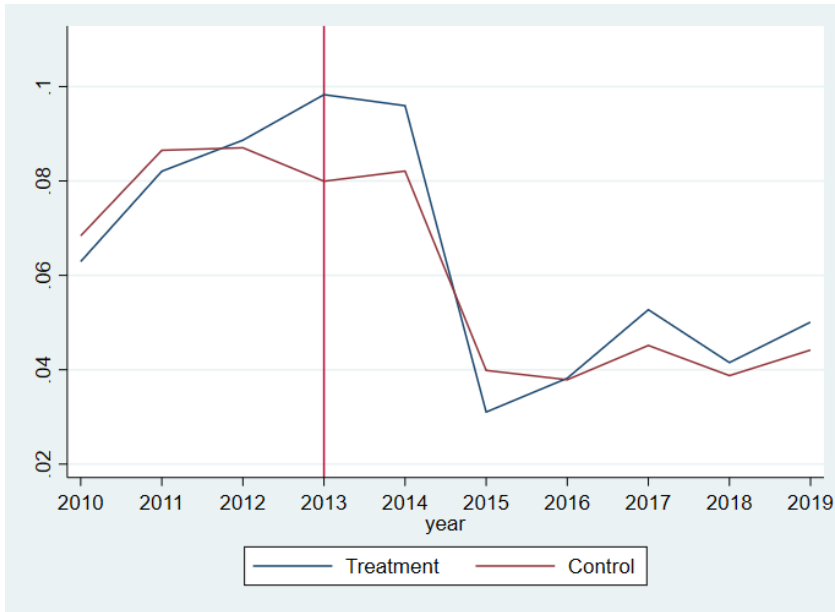
In the case of non-major appliances, the decline is much more pronounced with about a four-percentage point decrease in the control regions, and more than a six-percentage point decrease in the treatment regions. We can observe that the purchase of non-major appliances in treatment regions fell by about 60-percent in 2015, while it increased in the case of major appliances by about 15-percent in the same year.

Table 6: Unconditional DiD estimates for Propensity to purchase non-major appliances

	Pre-period	Post-period	Difference (post-pre)
T=1	0.0778	0.0586	-0.0192
T=0	0.081	0.053	-0.028
Diff-in-Diff			0.0088 (0.0077)

Robust standard error in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Figure 3: Propensity to purchase non-major appliances



5.3 Fixed effects estimation results

Next, I estimate DiD model for major electric appliances using fixed-effect model with a set of additional time-varying covariates, to see if the effect of IBR on propensity to purchase major electric appliances is robust to the inclusion of the household, and year fixed effects, as well as some additional time varying covariates. I include total household income, the total amount of discounts, and subsidies received by the household for utilities, the average price for the electricity, and household size as additional covariates.

Column 1 of Table 7 presents the results of the fixed effect estimations. I then repeat the same estimations (column 2 of Table 7) by applying the full tariff schedule for electricity as an instrument for the average electricity price to address any potential endogeneity concerns resulting from a non-linear electricity tariff schedule. Column 3 and Column 4 repeat the estimations but with application of the coarsened exact matching (cem) technique prior.

Table 7: Results

	(1) FE	(2) FE matched	(3) FE 2SLS	(4) FE_2SLS matched
DID	0.0224* (0.013)	0.0224* (0.013)	0.0228* (0.013)	0.0229* (0.013)
lnPrice	-0.0111 (0.023)	-0.0120 (0.023)	-0.0128 (0.023)	-0.0137 (0.023)
lnIncome	0.0463*** (0.004)	0.0471*** (0.004)	0.0463*** (0.004)	0.0471*** (0.004)
lnDiscounts	0.0008 (0.001)	0.0007 (0.001)	0.0008 (0.001)	0.0007 (0.001)
lnSubsidies	0.0014** (0.001)	0.0013* (0.001)	0.0014** (0.001)	0.0013* (0.001)
HHsize	0.0032 (0.003)	0.0024 (0.003)	0.0032 (0.003)	0.0024 (0.003)
year11	0.0066 (0.006)	0.0072 (0.006)	0.0067 (0.006)	0.0073 (0.006)
year12	0.0104* (0.006)	0.0084 (0.006)	0.0104* (0.006)	0.0085 (0.006)
year13	0.0159** (0.006)	0.0152** (0.007)	0.0160** (0.006)	0.0153** (0.007)
year14	0.0084 (0.006)	0.0076 (0.007)	0.0084 (0.006)	0.0077 (0.007)
year15	-0.0209*** (0.006)	-0.0209*** (0.006)	-0.0208*** (0.006)	-0.0208*** (0.006)
year16	-0.0122** (0.006)	-0.0125** (0.006)	-0.0122** (0.006)	-0.0125** (0.006)
year17	-0.0029 (0.006)	-0.0023 (0.007)	-0.0031 (0.006)	-0.0025 (0.007)
year18	-0.0103 (0.007)	-0.0115 (0.007)	-0.0105 (0.007)	-0.0118* (0.007)
year19	0.0015 (0.008)	0.0014 (0.008)	0.0012 (0.008)	0.0010 (0.008)
_cons	-0.3586** (0.148)	-0.3607** (0.150)		

<i>N</i>	53040	51608	53040	51608
adj. <i>R</i> ²	0.02	0.02	0.02	0.02
F	15.3988	14.9204	15.4031	14.9256
p	0.0000	0.0000	0.0000	0.0000
Robust standard errors in parentheses * <i>p</i> < 0.1, ** <i>p</i> < 0.05, *** <i>p</i> < 0.01				

Across models, we can see that there is some evidence of the relationship between the IBR pricing scheme and the propensity to buy major electric home appliances. The DID estimator characterized by the interaction of the binary treatment indicator with the binary indicator for the post treatment period is positive and statistically significant both in ordinary FE specification, and when instrumenting the price of electricity with full tariff schedule.

The magnitude of the effect indicates that the propensity to purchase major electric appliances is more than 25 percent (or 2.2-2.3 percentage points) higher in the regions with the IBR tariff scheme. The estimates are mostly in line with the unconditional DID estimate reported in table 5, although the statistical significance falls from 5-percent to 10-percent. Taking into account that in the FE specifications we control both for observed and unobserved time-invariant factors, along with some additional time-varying covariates included into the model this fall in the significance is not surprising.

Instrumenting for the average prices of electricity with the full tariff schedule does not alter the estimation results. The coefficients estimated by the FE, are practically identical to the estimators in the 2SLS context, which mitigates the potential endogeneity concerns in our model specifications⁹.

Regressions based on coarsened exact matching (cem) procedure perform reasonably well in our specification. We “coarse” our continues variables (square footage of the dwelling, size of the household, and household income) into 10 quantiles, and match the treatment and control units according to the quantiles they located in, and the binary household

⁹ First stage regression results are available from the author upon request.

characteristics: single family or multi apartment, location (urban, rural), whether the household is connected to the central delivery of hot water, and central heating.

The multivariate L1 distance statistics (see, Blackwell et al., 2009) indicates a slight improvement in balance of covariates between groups. First, we run an L1 distance statistics on an unmatched data which will then serve as a point of comparison (a baseline reference) for the matched data. If L1 statistics is closer to zero (one indicating perfect imbalance, while zero indicating a perfect balance of covariates) on a match data, as compared to its unmatched counterpart then we can argue that there was an improvement in balance of covariates across the treatment and control groups after the matching procedure.

In our case, the multivariate L1 distance statistics for the unmatched data is 0.636, while for the matched data it is equal to 0.57, indicating an overall improvement in the balance between two groups.

Overall, out of total 56,820 observations in control regions, and 5814 observations in treatment regions, only 1471 observations from control regions, and 1 observation from treatment regions were not matched between groups. The remaining observations were matched.

Applying the matching prior to the estimation of DID also did not produce any significant difference in estimation results. The regression coefficients are fairly close to their unmatched counterparts. I project that this is mainly the result of the IBR policy being implemented practically exogenously across regions (see, Veretennikova, 2014), which in turn could eliminate strong systematic differences between treatment and control groups.

Examining the covariates across all specifications I find no evidence of the effect of the level of the price of electricity (as opposed to its structure represented by the DID term) on the

propensity to purchase electric appliances by households. The coefficient on the average price is statistically insignificant. This finding is in accord with the recent study of Jacobsen (2015) who also concludes that electricity prices do not affect the purchasing decision of the Energy Star certified home appliances in the US.

The effect of the total household income, on the other hand, is positive and statistically significant at 1-percent. The estimation results suggest that a one percent increase in income results in about half a percent increase in the probability of purchasing major electric appliances¹⁰.

Both household size, and the discounts for the utilities, have statistically insignificant association with the propensity to purchase electric appliances. Subsidies have a positive and statistically significant association, although the coefficient is small in size, which suggests that the relationship is insignificant economically.

6. Conclusion

Using the variation resulting from an implementation of the IBR tariff for residential electricity in three experimental regions in Russia, and household panel data, I examine the relationship between the IBR pricing and the propensity of the households to purchase major electric appliances. I find evidence that in the regions where the IBR pricing was implemented the households' tendency to purchase the major electric appliances increased by more than 25 percent (2 percentage points). This result is robust both in standard fixed effects regression, as well as when instrumenting for the electricity prices with full tariff schedule.

It should be noted, however, that I cannot observe from the data the actual energy efficiency rating of any of the purchased appliances. As such, I am unable to comment on whether

¹⁰ The elasticity in lin-log specification is obtained by: $b*(1/Y)$

consumers respond to IBR pricing by purchasing more energy-efficient appliances. I am also unable to comment on how IBR pricing affects investment in other types of household products, such as more efficient light bulbs, furnaces, or insulation.

However, taking into account the robust trend of newer appliances being more energy-efficient, I can suggest that consumers that purchase new electric appliances are also purchasing more energy-efficient appliances. If this proposition holds the results of this paper can suggest that price-based energy policies are an effective tool not only in shaping the behavior of the household but also in shaping the households' behavior towards higher energy efficiency, which is considered one of the lowest-cost opportunities for reducing carbon emissions.

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Appendix: Electricity Tariff Schedules. Source: gks.ru, (2020)

Figure A1: Electricity Tariff Schedule for Krasnoyarsk (2010-2019).

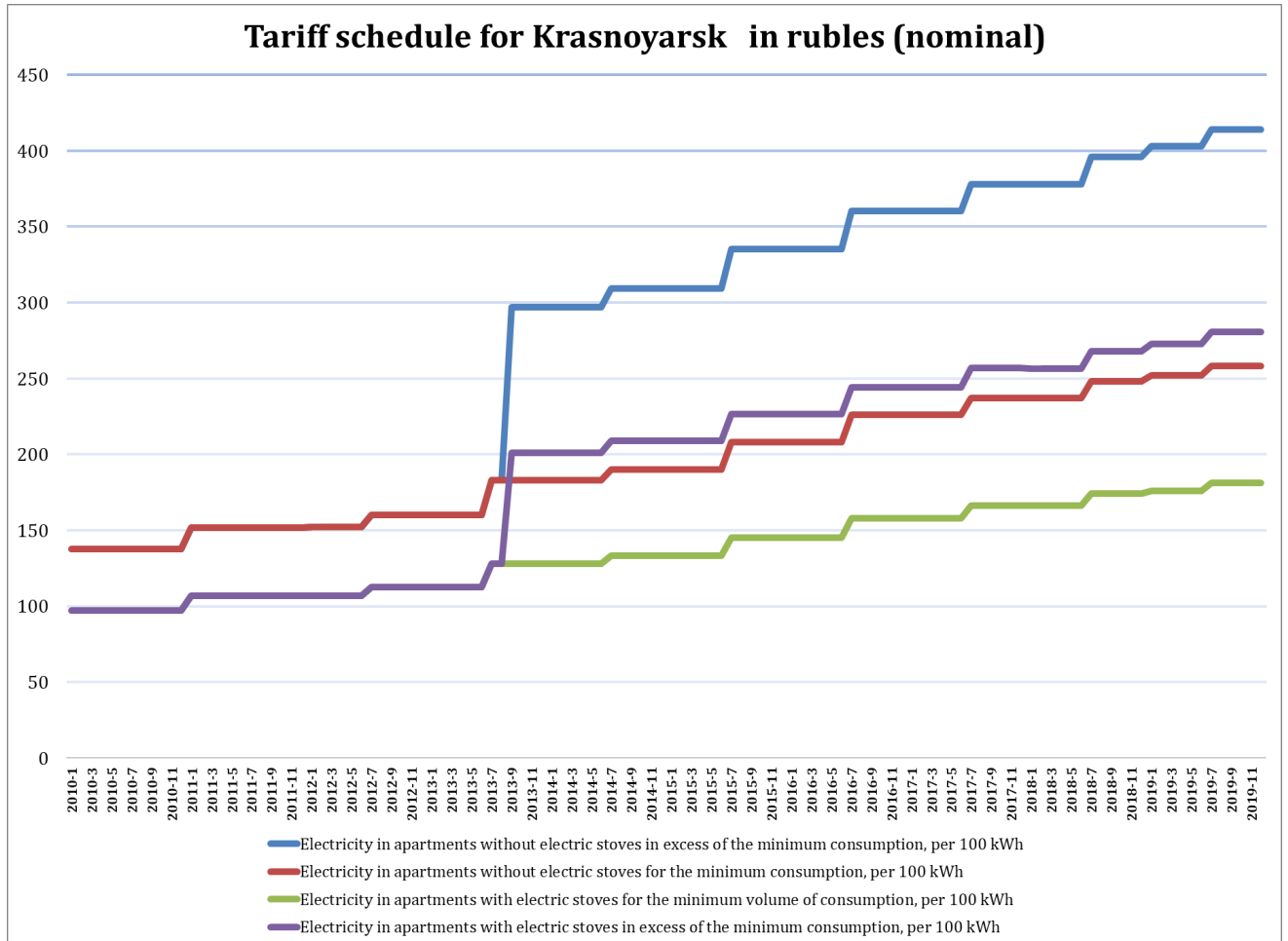


Figure A2: Electricity Tariff Schedule for Rostov (2010-2019)

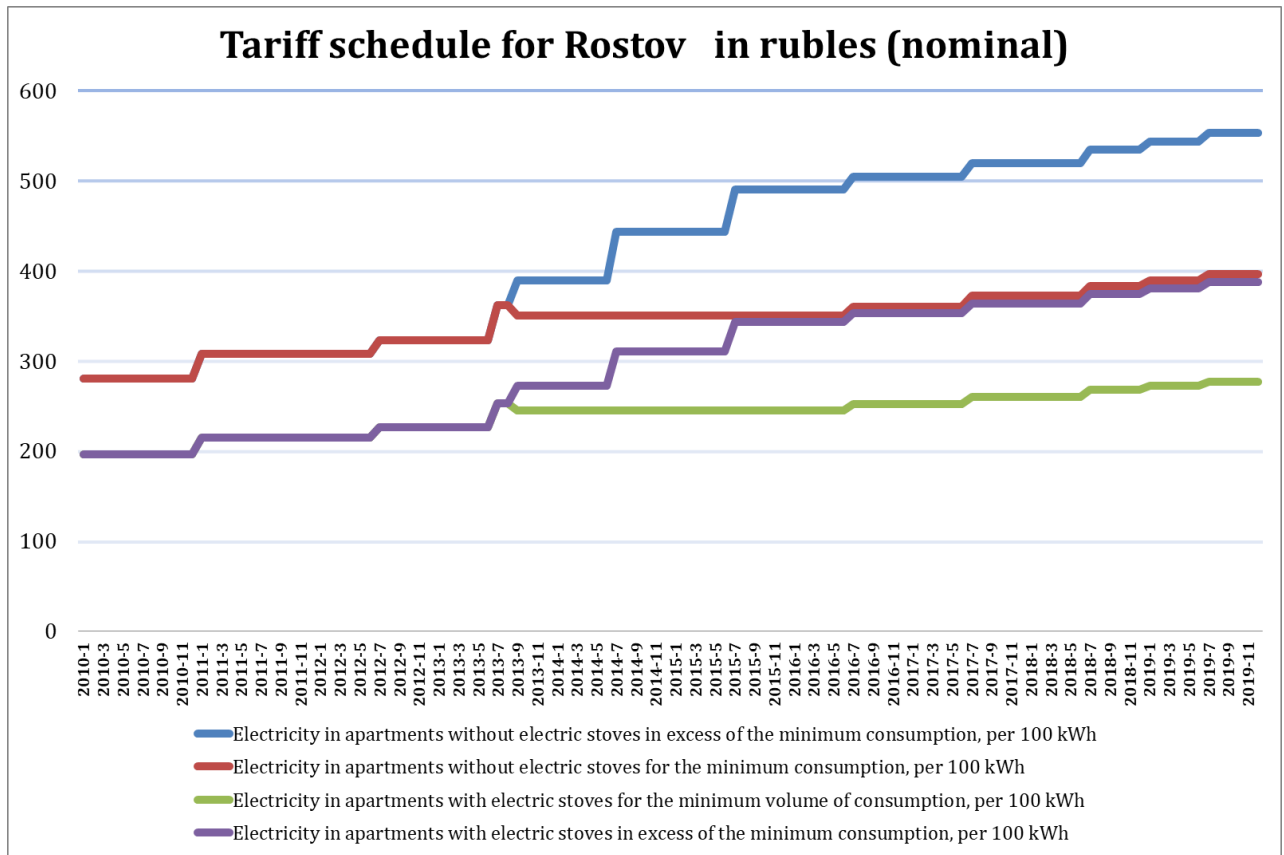


Figure A3: Electricity Tariff Schedule Nizhny Novgorod (2010-2019)

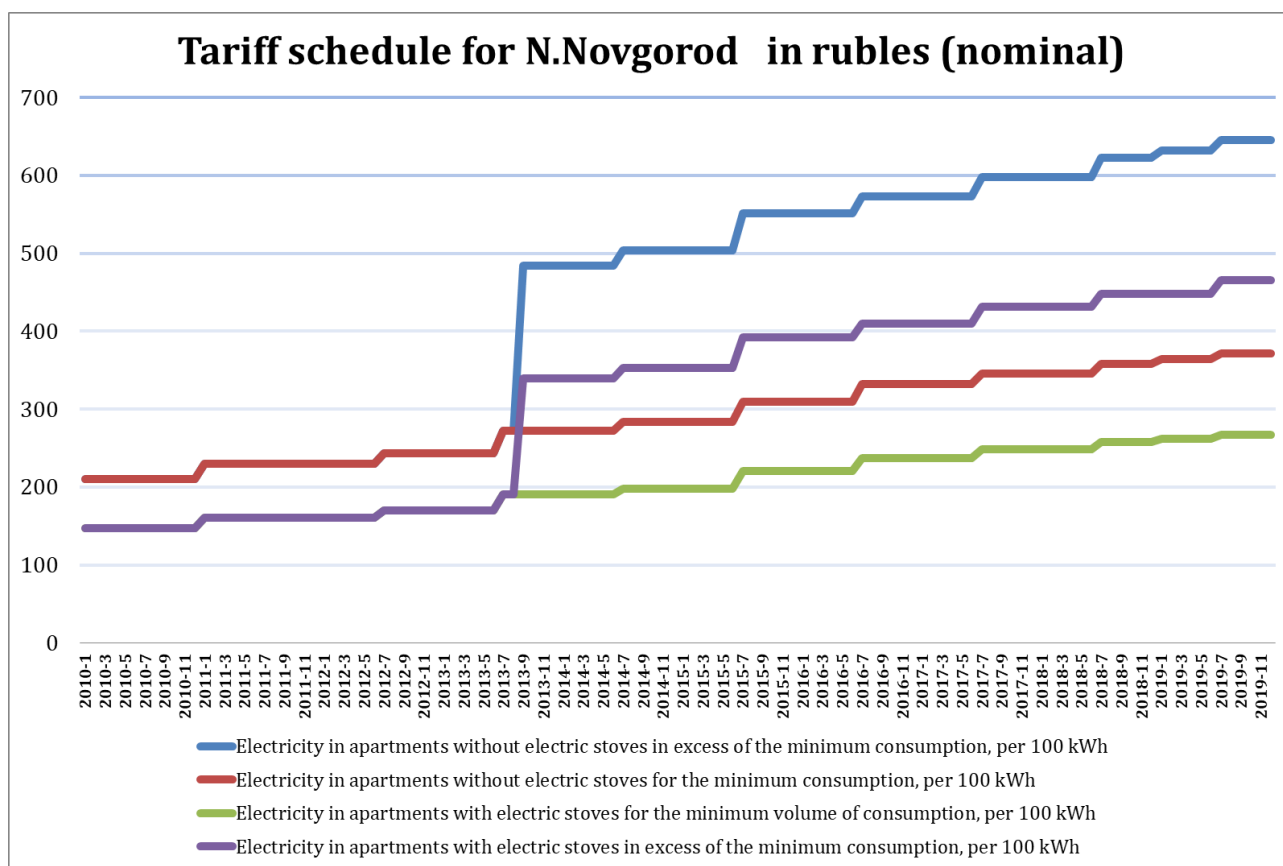
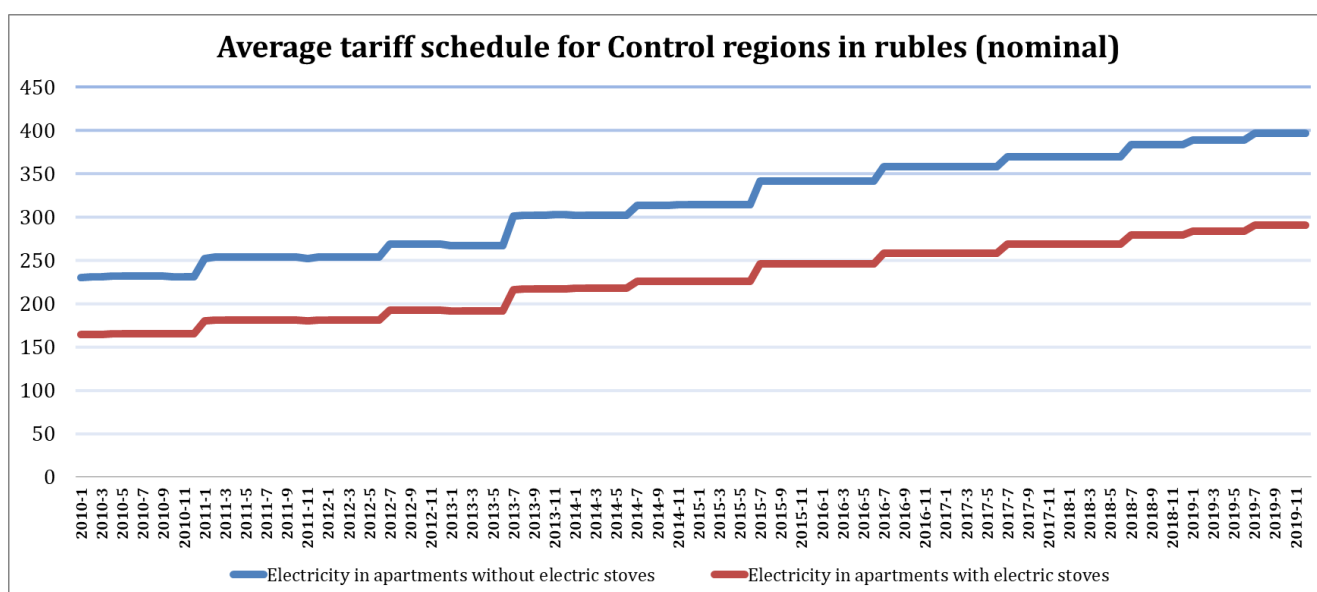


Figure A4: Tariff Schedule for Control regions (mean) (2010-2019)



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