Svetlana Egorova

Natalya Volchkova

Natalya Tourdyeva

Sectoral and regional analysis of industrial electricity demand in Russia

Working Paper #

This paper is based on the joint work of Natalya Volchkova, Svetlana Egorova and Natalya Tourdyeva in the framework of research project "Some Aspects of the Performance of Russian Enterprises: electricity consumption and innovation activity" under the supervision of prof. K.V. Yudaeva (Ph.D., NES /CEFIR) and N.V. Volchkova (Ph.D.,CEFIR).

The research was supported by Ford Foundation, World Bank, John D. and Catherine T. MacArthur Foundation. Financial contribution was also done by Carnegy Foundation and SIDA.

Moscow
2004

Egorova Svetlana, Volchkova Natalya and Natalya Tourdyeva. Sectoral and regional analysis of industrial electricity demand in Russia / Working Paper #. – Moscow, New Economic School, 2004. –17p. (Engl.)

Over last year electricity reforms in Russia are widely discussed among politicians and researchers as well. In spite of the importance of these reforms and their consequences for overall economy, there is no consensus among politicians and researchers even with respect to the understanding of current situation with electricity pricing and electricity consumption in industrial sector. Given the lack of quantitative estimations of current electricity demand we can not predict the results of such changes for Russian industrial output and energy demand and therefore, to provide a correct predictions of the effects of electricity reforms for economic and social parameters of country development.

This study analyses Russian industrial electricity demand over the last 5 years, elasticity of electricity demand in industries and regions of Russian Federation. Our estimations of price elasticity of electricity demand lie in interval -0.2 -- -0.4 which is close to estimations of elasticities for US and Europeam firms. We also fins evidence of the decline in electricity intensity of Russian industrial production. As far as substitution possibilities between labor and electricity in production are concerned we did not get the reliable result.

Key words: elasticity of industrial electricity demand

Егорова С., Волчкова Н., Турдыева Н Секторальный и региональный анализ промышленного спроса на электроэнергию в России. / Препринт # BSP/2004/071 E. - M.: Российская Экономическая Школа, 2004. – 17 с. (Англ.)

Проводимая в настоящее время реформа электроэнергетического сектора затрагивает все отрасли промышленности и регионы страны, поэтому важность понимания возможных последствий реформ не вызывает сомнения. Несмотря на всю важность этого вопроса, тем не менее, консенсус отсутствует даже в оценке того, какова на сегодняшний день ситуация в электроэнергетике страны. Данная работа посвящена анализу энергопотребления на российских промышленных предприятиях в течение пяти лет, оценке эластичности спроса на электроэнергию со стороны промышленных предприятий и отраслей промышленности в целом и в разрезе регионов.

Основой для исследования служат панельные данные на уровне фирм, а именно основные показатели финансово-экономической деятельности и данные о потреблении электроэнергии по промышленным предприятиям в четырех регионах РФ (Волгоградская, Воронежская, Пермская и Самарская области) за 1998—2002 г.

В ходе исследования была проверена гипотеза о том, что спрос на электричество со стороны промышленных предприятий эластичен, оценка эластичности спроса на электроэнергию составила -0.2 — -0.4, что совпадает с результатами оценки эластичности для промышленных предприятий США и Европы. Также анализ данных указывает на значительное снижение затрат на электроэнергию на единицу продукции в рассматриваемый промежуток времени. В тоже время мы не нашли значительных свидетельств замещения между трудом и электроэнргией в производстве, что характерно для промышленности других стран.

Ключевые слова: эластичность промышленного спроса на электроэнергию

ISBN

1. Introduction

Over last year electricity reforms in Russia are widely discussed among politicians and researchers as well. In spite of the importance of these reforms and their consequences for overall economy there is no consensus among politicians and researchers with respect to the understanding of current situation with electricity pricing and electricity consumption in industrial sector. Given the lack of quantitative estimations of current electricity demand we can not predict the results of such changes for Russian industrial output and energy demand and therefore, to provide a correct predictions of the effects of electricity reforms for economic and social parameters of country development.

This study analyses Russian industrial electricity demand over the last 5 years, elasticity of electricity demand in industries and regions of Russian Federation. The estimation of industrial electricity demand elasticity is an important field of economic research around the world. Its importance is determined first of all by high needs of economic policy to base its decisions on quantitative estimations of their consequences. At the same time no one of this kind of research has been done on Russian economy yet. Our study presents the first step in this direction. Its importance is emphasized by the reforms of electricity sector undergoing in Russia right now and urgent necessity to evaluate them.

Our estimations of price elasticity of electricity demand lie in interval -0.2 -- -0.4 which is close to estimations of elasticities for US and European firms. We also find evidence of the decline in electricity intensity of Russian industrial production. As far as substitution possibilities between labor and electricity in production are concerned we did not get the reliable result.

The paper is organized as follows. In the next section we discuss the existing evidence on elasticity of industrial electricity demand around the world. In section 3 we present the data and discuss the methodology of our research. Empirical results are presented in section 4, last section concludes.

2. Literature review

In this research we use methodology developed by Berndt and Wood (1995), who investigated industrial demand for energy in United States over the period 1941—1971. The energy demand function that is used in their research is the derived demand for energy and non-energy inputs from production technology. The authors assumed that production technology employs four inputs (capital, labor, energy and all other intermediate materials) and can be stylized as the translog cost function since this functional form places no a priori restrictions on the Allen partial elasticities of substitution among inputs. For empirical estimations authors use the price indexes and firm level data on cost shares of the four inputs and evaluate own and cross elasticities using the iterative three-stage least squares estimations.

For comparative purposes it is worth to mention the results obtained by Berndt and Wood (1975). They find that, first, energy demand is price responsive (the own price elasticity is about –0,47), second, energy and labor are slightly substitutable (the Allen partial elasticity of substitution is about 0,65), third, energy and capital in production are complements (the elasticity of substitution is about –3.2) and, finally, capital and labor are substitutable (the elasticity of substitution is about 1,01).

These results are very important because of widespread adoption in economic research of the value added specification of technology that depends only on capital and labor which is the outcome of the following assumptions:

– quantity ratios of energy consumption to total output and all intermediate materials to total output always change in the same proportions (Leontief aggregation condition);

– the prices of energy and all other intermediate materials and the price of output always change in the same proportions (Hicksian aggregation condition);

– capital and labor are weakly separable from energy and all other intermediate materials.

While analyzing the validity of this value added specification on the dataset of US firms Berndt and Wood find that these conditions are not satisfied and their conclusion is that reliable energy demand predictions cannot be made on the basis of above value added specification, and, instead, need to take into account expected values of output, prices of capital, labor, energy and all other intermediate materials.

This kind of methodology was exploited in the analysis of European industrial data. Paper by Bjorner, Togeby and Christensen (1998) investigates the industrial energy demand in Denmark at micro level and analyses the impact of Danish policy with regards to industrial energy consumption. Using data at the company level has several advantages. First, data at micro level are suited for analysis of policy instruments that are individual to each company (for example, subsidy for investment in energy efficiency). Second, information at company level may be very rich with many variables and with large heterogeneity in these variables. Usually such information is lost in aggregated data.

Bjorner, Togeby, Christensen use panel database for Danish industrial firms' energy consumption. Their database contains information on energy consumption spaced out by different types of energy (electricity, coal, natural gas and so on) and accounts statistics (value added, production, number of employees, wages) for seven years over the period from 1983 till 1996. The database covers about 90% of all production and energy consumption in Danish industry and most companies can be identified in several years (in average a company can be found 3.5 times in this database). For two types of energy — electricity and central heating — authors have information about consumption and expenditures for each company so they can calculate average prices for each company for these two sources of energy.

The authors estimate electricity demand assuming that firm's electricity consumption depends on the value added in fixed prices, the relative price of electricity and on exogenous technological changes. Further, they assume the firm's individual intercept which captures unobserved variables. The authors argue that the fixed effects panel model is more preferable. Moreover, they find that the time dummy should be included in the regression analysis to capture technological changes.

In the fixed effect model the own elasticities of electricity and non-electricity energy demands are about -0,4 — -0,5 and -0,5 — -0,6 respectively, which close to the one obtained by Berndt and Wood (1975) estimated on US firms' data.

Bjorner, Togeby and Christensen advanced their research by analyzing what firms' parameters influence the value of price elasticity of electricity and energy demand. They find that the price elasticity of energy demand varies by industrial sectors, while the price elasticity of electricity demand varies according to other firm characteristics than industrial sector. Moreover, there are opposite effects of characteristics on the electricity and energy price elasticities. Namely, they find that

– price elasticity of electricity demand increases with electricity intensity, while price elasticity of energy demand decreases with energy intensity.

– price elasticity of energy demand increases with the size of company, while price elasticity of electricity demand in not influenced by size.

As far as the research of energy industrial demand of Russian firms is concerned we were able to find only a few references. Solodnikova (2003) uses time-series analysis approach to estimate the price elasticity of industrial demand for gas in Russia over the period 1996-2000 and shows that it is insignificantly differ from zero for manufacturing sector.

While we were not able to find the research that evaluates the Russian industrial firm electricity demand we find at least one paper that estimates Russian households' electricity demand. Maitak (2003) studies the electricity demand of Russian households for electricity on the dataset of household electricity consumption in 74 Russian regions over the period from 1995 to 2001. It was found that price elasticity of households demand for electricity is insignificantly differ from zero and it was demonstrated that other factors such as income, the size of the household apartment, purchase of new electrical appliances have significant influence on electricity consumption.

3. Methodology and Data

In order to estimate the industrial electricity demand elasticity in Russia in this research we use the annual firm level data on revenues, expenses by categories (labor, intermediates), fixed assets, employment and volume of electricity consumption for large and medium industrial firms in four Russian regions (Volgoradskya, Voronezhskaya, Permskaya and Samarskaya oblasti) over the period 1998-2002. Only for one region (Permskaya oblast) we have data on firms' electricity expenses that enable us to calculate the average price of electricity for each firm. For the rest of firms we use official regional level of electricity tariffs with some exceptions. Since almost all data are in nominal terms we use 5-digit industries' producer price indexes.

While in the original dataset there were 8207 observations the number of data points used in this study is less because of missing data. Since not all of the data were presented in panel form the number of observations depends on what estimation technique we use for a particular exercise. Namely, the sub sample for cross-section estimations includes 5626 observations and the sub sample for panel estimations includes 4232 observations (928 firms).

The information about electricity tariffs for industrial consumers was obtained from the Regional database on electricity tariffs constructed in CEFIR. The database contains the levels of electricity prices collected from legislative documents from Regional issues of ConsultantPlus as well as all exceptions from these documents adopted at regional levels.

Table 1. Average tariffs over time, rub. per 1 kWh[1],[2]

	Volgogradskaya oblast			Voronezhskaya oblast	Permskaya oblast			Samarskaya oblast		
	High Voltage	Medium Voltage	Low Voltage		High Voltage	Medium Voltage	Low Voltage	High Voltage	Medium Voltage	Low Voltage
1998	0,35	0,35	0,35					0,31	0,31	0,31
1999	0,36	0,36	0,36		0,37	0,47	0,59	0,35	0,35	0,35
2000	0,53	0,53	0,53	0,53	0,43	0,57	0,71	0,46	0,46	0,46
2001	0,57	0,68	0,85	0,69	0,62	0,69	0,89	0,57	0,57	0,57
2002	0,78	0,98	1,15	0,84	0,67	0,89	1,13	0,68	0,85	0,96

Electricity tariffs for industrial consumers depend on the connected load. If the power is greater than 750 kilowatt, then companies have to pay the two-part tariff: for load and for electricity consumed. Unfortunately, we do not have information on firms' connected load in our dataset so we use tariffs for consumers with connected load less than 750 kilowatt. This approach seems to be especially justified as we exploit the fixed effect panel data approach for estimations.

As far as the sectoral distribution of our sample is concerned a large number of firms in the sample are from engineering industry and food industry. The comparison of our sample with

[1] Since almost in all regions tariffs were changed several times a year we use the weighted average prices that are calculated as a prices multiplied by the shares of year when the prices were valid.

[2] Voltage: high — more than 110 kilowatt, medium — 35-1 kW, low — 0,4 kW.

countrywide distribution of industrial firms shows that timber and light industries are slightly underrepresented in our sample while food industry is over represented in it.

In the tables 2-4 we present the overall, sectoral and regional distributions of firms in our dataset.

Table 2. Descriptive statistics[3]

Characteristics	Number of observations	Mean	St. Dev.	Min	Max
Firms' characteristics					
Electricity consumption, thous. of kWh	5626	21 932	127 108	1	2 577 444
Revenues, thous. Rbl	5626	104 779	803 198	5	33 700 756
Fixed assets, thous. Rbl	5409	49 708	428 478	0,3	17 560 792
Cost of production, thous. Rbl	5625	82 156	645 742	7	27 345 994
Cost of intermediates, thous. Rbl	4958	65 084	536 299	1,3	21 327 842
Labor costs, thous. Rbl	4980	10 735	76 782	3	3 307 442
Number of employees, thous.	5493	663	3 035	4	121 628
Investment, thous. Rbl	2634	17 076	95 303	0,4	2 134 720
Electricity tariffs[4]					
High voltage, Rbl per thous. kWh	5626	234	54	96	443
Medium voltage, Rbl per thous. kWh	5626	263	70	115	563
Low voltage, Rbl per thous. kWh	5626	298	99	115	707

Table 3. Sectoral distribution of firms in the sample

Industrial sectors	Number and share of companies in the sample				Share countrywide[5]
	Cross-section analysis		Panel analysis		
	Number	Share	Number	Share	
Power and fuel industry	155	2.8	28	2.9	1.9
Metallurgy	158	2.8	24	2.5	2.5
Chemical and petrochemical industry	335	6.0	59	6.1	5.6
Machinery	1541	27.4	252	26.0	36.7
Timber industry	471	8.4	69	7.1	15.0
Industry of building materials	550	9.8	97	10.0	6.6
Light industry	516	9.2	76	7.9	12.0
Food industry	1322	23.5	260	26.9	17.5
Miscellaneous	578	10.3	103	10.6	2.2

Table 4. Regional distribution of firms' characteristics (means)

	Volgogradskaya oblast	Voronezhskaya oblast	Permskaya oblast	Samarskaya oblast
Electricity consumption, thous. of kWh	23 632	7 518	23 792	24 579

[3] Here and further means of characteristics measured in rubles are given in constant (1998) prices.

[4] Since the electricity consumption is in thousand of kWh the tariffs are presented in rubles per 1 thousand of kWh.

[5] Goskomstat data for 2001

Revenue, thous. Rbl	56 753	48 909	113 044	175 847
Fixed assets, thous. Rbl	30 513	17 678	56 217	78 345
Cost of production, thous. Rbl	46 244	42 855	78 133	147 971
Inputs, thous. Rbl	48 913	29 404	56 057	144 220
Labor costs, thous. Rbl	6 633	7 144	11 299	20 087
Number of employees, thous.	549	528	655	869
Investment, thous. Rbl	13 288	3 095	19 838	24 065
Electricity tariffs				
high voltage[6], Rbl per thous. kWh	232	250	240	219
medium voltage[4], Rbl per thous. kWh	252	250	302	229
low voltage[4], Rbl per thous. kWh	275	250	382	233

Variances in mean values by regions may be explained by different industrial structure of these regions. For example, while food industry is rather developed in Voronezh region (the share of food industry in regional GDP is about 25%) fuel industry (25,6%) and chemical and petrochemical industries (18%) are the major sectors in Perm region and more than a half of regional GDP is produced by machinery companies in Samarskaya oblast, mostly in motor-car construction. Due to this the "the average company" in Samara seems to be significantly large than average company in other regions.

The evolution of firms' characteristics in the dataset over time is presented in the table 5.

Table 5. Means of firms' characteristics over time

	1998	1999	2000	2001	2002
Electricity consumption, thous. of kWh	18 566	20 593	22 206	23 107	24 227
Revenue, thous. Rbl	73 862	95 007	111 341	115 728	119 321
Fixed assets, thous. Rbl	70 915	46 327	45 067	42 339	48 257
Cost of production, thous. Rbl	60 697	69 294	84 983	91 078	97 964
Inputs, thous. Rbl	44 310	51 171	68 047	72 044	75 590
Labor costs, thous. Rbl	7 707	8 525	9 644	11 338	14 408
Number of employees, thous.	608	598	677	693	719
Investment, thous. Rbl	17 501	17 295	16 567	18 496	15 753
Electricity tariffs					
high voltage[7], Rbl per thous. kWh	317	208	206	217	235
medium voltage[5], Rbl per thous. kWh	353	232	225	235	288

[6] Electricity tariffs are calculated by using regional deflators.

[7] In constant (1998) prices

low voltage[5], Rbl per thous. kWh	397	260	245	272	332

We see that the electricity consumption increases over time and it goes along with the growth of output and employment. However, while the growth of the mean of revenues is about 60% in 2002 compare to 1998, the increase in employment is 80%, the increase in electricity consumption is only 30%. As far as electricity prices are concerned in constant prices the level of tariffs decreases from 1998 to 2000 by 40% and slightly increases afterwards.

Presented above distributional features of the sample under study indicate that we have enough cross-sectional and time variation in the price of electricity to be able to estimate the own price elasticity of industrial electricity demand in Russia.

Interesting dynamical features of electricity consumption can be also inferred from descriptive statistics. There are widespread believes in Russia that because of aged capital stock in Russian industrial firms and low price of electricity in the country firms do not switch to energy saving technologies of production. Our firm level data indicate the opposite, namely, from data presented in table 6 we see that over time there is a clear tendency of the decline in electricity expenses.

Average consumption of electricity per 1 ruble of output

Table 6. Means of electricity consumption per 1 ruble of output[8]

Year	Electricity intensity of nominal output[6], kWh per 1 ruble
1998	0.143 kWh
1999	0.070 kWh
2000	0.042 kWh
2001	0.026 kWh
2002	0.020 kWh

This data and data from the table 5 indicate that along with the decline of real price of electricity by 25% from 1998 to 2002, the decline of electricity utilization in the value of final output is 7 fold over the same period of time. That is there clearly a huge reduction of electricity intensity in industrial firms over the time that probably is due to investment in energy-saving technologies. One of the possibilities to test this hypothesis is to look at the effect of the investments in fixed assets on the energy intensities of output. The corresponding results are presented in the next section.

In order to specify the equation for estimation of electricity demand elasticity we follow the assumptions provided by Berndt and Wood (1975). We assume that firm's production technology can be presented as Cob-Douglas one with two inputs - electricity and all other inputs aggregated in

[8] Output is measured in constant (1998) prices

the one. All firms are price-takers on the electricity market and therefore they treat electricity tariffs as exogenous ones. Given tariff rate the firm chooses optimal level of electricity demand in order to minimize the costs of production. The corresponding derived demand for electricity can be written in the following way:

$$\log(\text{Energy}) = \alpha + \beta_1 \log\left(\frac{\text{Revenue}}{\text{Price Deflator}}\right) + \beta_2 \log\left(\frac{\text{Energy Price}}{\text{Price Deflator}}\right) \qquad (1)$$

where *Energy* stands for electricity consumption (in thousand of kwh), *Revenue* — revenue in constant price (in thousand of rubles), *Price* — weighted average tariffs for electricity during a year (in rubles per 1 thousand of kWh), Price Deflator — a sectoral deflator.

Given the panel structure of the sample under study the following model will be estimated:

$$\log(\text{Energy}_{\text{it}}) = \alpha + \beta_1 \log\left(\frac{\text{Revenue}_{\text{it}}}{\text{Price Deflator}_{\text{t}}}\right) + \beta_2 \log\left(\frac{\text{Energy Price}_{\text{it}}}{\text{Price Deflator}_{\text{t}}}\right) + f(t) + \upsilon_{it} \qquad (2)$$

$$\upsilon_{it} \sim iid\ N(0, \sigma_\upsilon^2 I)$$

where $f(t)$ stands for technological changes and we use the simplest way of introducing them in the model – through time dummies, that is by putting $f(t) = \lambda_t$.

4. Estimation results

Elasticity of electricity demand

As we have already mentioned being not able to identify the exact tariff rate faced be a particular firm in the sample we use all 3 levels of tariffs for estimation purposes. We also introduce *the size-dependent tariff* which is constructed based on the following considerations. We assume that the level of electricity tariff depends on the size of the firm. It seems that large companies are more likely to have electricity transformation facility of their own so they can consume cheaper high voltage electricity and then transform it to necessary level, while small companies due to scale effect usually are lack of such opportunities and buy more expensive low voltage electricity. It allows us to assign the tariff rate for the firm that is a function of its size. The results of cross-section pooled regression are presented in table 7.

Table 7. OLS estimations on pooled data

Dependent variable Log(Energy consumption)

	Tariff (high volt.)		Tariff (medium v.)		Tariff (low volt.)		Size-dependent tariff	
Log(Revenue)	0.94	**	0.94	**	0.94	**	0.93	**
	(127,89)		(27,94)		(127,96)		(124,51)	
Log(Price)	**-0,10**		**-0.14**	**	**-0.13**	**	**-0.41**	**
	(-1,41)		(-2,34)		(-2,69)		(-6,92)	
R-squared	0.74		0.74		0.74		0.75	
Number of obs.	5626		5626		5626		5626	

*-5%, ** - 1% level of significance,   t-statistics in parenthesis

As it was expected the estimation of price elasticity of demand depends on the assigned level of tariffs. If all companies pay for electricity as if they use high voltage of electricity it appears that electricity demand is not price responsive and the elasticity of electricity demand is around -0.15 if we use medium and high voltage levels of tariff for all firms in the sample. The more reliable estimations seem to be the one that is based on the size-dependent levels of tariffs which gives us the estimation of elasticity equal to -0.4. This result is quite surprising since similar values of elasticity of electricity demand were obtained for US firms (Berndt and Wood, 1975) and for Danish firms (Bjorner, Togeby and Christensen, 1998).

The results of fixed effect panel data estimations are presented in table 8.

Table 8. Fixed effect panel data estimation.

Dependent variable Log(Energy consumption)

	Tariff (high volt.)	Tariff (medium v.)	Tariff (low volt.)	Size-dependent tariff
Log(Revenue)	0.50 **	0.49 **	0.50 **	0.50 **
	(40.19)	(40.03)	(40.01)	(39.89)
Log(Price)	**-0.27** **	**-0.18** **	**-0.15** **	**-0.32** **
	(-4.41)	(-3.18)	(-3.27)	(-6.34)
R-squared within	0.34	0.34	0.34	0.34
N of groups	968	968	968	968

*-5%, ** - 1% level of significance,   t-statistics in parenthesis

This results are close to the previous ones obtained on pooled data and allow us to suggest the level of elasticity of electricity demand of Russian industrial sector to be around -0.3 - -0.4.

More support for this result we find by estimating the data from one of the regions, Permskaya oblast, that are unique in the sense that besides information on firms' electricity consumption we got data for firms' payment for electricity, based on which we are able to calculate firm-specific level of electricity price. The corresponding estimations are presented in table 9.

Table 9. OLS with fixed 5-digit industry and year effects on pooled data from Permskaya oblast

Dependent variable Log(Energy consumption)

	Firm-specific tariff
Log(Revenue)	0.75 **
	(47.54)
Log(Price)	**-0.41** **
	(-13.18)
Adj. R-squared	0.88
N of observations	1861

*-5%, ** - 1% level of significance,   t-statistics in parenthesis

Regional and sectoral specific effects

In order to explore whether there is a regional difference in the price elasticity of electricity demand we perform the estimations of equation (2) introducing three additional variables, namely, the log of electricity price interacted with three regional dummies. The benchmark region is Permskaya oblast. The results are presented in table 10.

Table 10. Panel fixed effect estimations of regional-specific effects

Dependent variable Log(Energy)

	Tariff (high volt.)	Tariff (medium v.)	Tariff (low volt.)	Size-dependent tariff
Log(Revenue)	0.50 **	0.50 **	0.50 **	0,50 **
	(40,27)	(40,16)	(40,07)	(39,90)
Log(Price) – Perm obl.	**-0.24** **	**-0.13** **	**-0.08**	**-0,26** **
	(-3,78)	(-2.14)	(-1,56)	(-4,62)
Δ Volgograd obl.	**-0.19** **	**-0.20** **	**-0,17** **	**-0,17** **
	(-2,56)	(-2,82)	(-2,50)	(-2,50)
Δ Voronezh obl.	**0.22**	**0.09**	**0.08**	**0,13**
	(1.14)	(0,46)	(0,42)	(0,65)
Δ Samara obl.	**-0.16** *	**0.09**	**0.13** *	**0,03**
	(-1,68)	(1,08)	(1,75)	(0,38)
R^2 within	0,34	0,34	0,34	0,34
N of groups	968	968	968	968

*-5%, ** - 1% level of significance, t-statistics in parenthesis

The result indicates that the only significant difference in the elasticities of electricity demand among regions is in Volgogradskaya oblast which we can be driven by differences in industrial structures of the regions. Therefore the next exercise we perform is the estimation of the sectoral differences in demand for electricity responsiveness to changes in tariffs. The results are presented in table 11.

Table 11. Panel fixed effect estimations of sectoral differences in elasticity. Benchmark sector – machinery.

Dependent variable Log(Energy)

Industrial sector	Elasticity
Log(Price) - machinery	-0.27 **
	(-2.79)
Δ Power and fuel industry	-0.11
	(-0.71)
Δ Metallurgy	-0.29 *
	(-1.79)
Δ Chemical and petrochemical industry	0.02
	(0.12)
Δ Timber industry	-0.01
	(-0.11)
Δ Industry of building materials	-0.29 *
	(-1.91)
Δ Light industry	0.02
	(0.16)
Δ Food industry	-0.10
	(-1.10)
Δ Miscellaneous	0.11
	(1.07)

*-5%, ** - 1% level of significance, t-statistics in parenthesis

According to this estimation while machinery, power and fuel, chemical, timber light and food industries' electricity demand elasticities are not significantly differ and are equal to -0.27, the elasticities in metallurgy and building materials industries are as twice as higher. However we do not find the positive correlation between the value of elasticities and electricity intensities as was found in Bjorner, Togeby and Christensen (1998) for Danish firms. We explain this lack of correlation, first of all, by a very insignificant differences in electricity intensities among industrial sectors in Russian economy and, second, by rapid changes in electricity intensities that we observe in all sectors of Russian economy over the period of time under consideration as can be seen from table 6. The interesting question that arises with regard to these changes is how they are related with the electricity price changes.

Investments and electricity efficiency

In order to answer this question, first, we look at the relation between firms' investments in fixed assets and electricity intensities. As a control variable we use lagged value of electricity intensities. The corresponding results are presented in table 12.

Table 12. Effect of investments in fixed assets on electricity intensity: random effect panel data estimation

All variables in logarithms. Dependent variable - Energy intensity		
Lagged value of energy intensity	0.41	**
	(0.01)	
Investments in fixed assets	-0.06	**
	(-0.01)	
R-squared within	0.50	
Number of groups	671	
*-5%, ** - 1% level of significance, standard errors in parenthesis		

We find out an empirical support for an expected result that investments in fixed assets positively affect electricity intensity decline. It allows us to argue that firms' new investments in fixed assets are more electricity-efficient than existing stock of fixed capital. While we observe the substantial increase in firms' revenues over the period 1998-2002 around 40% on average the decline in energy intensity is even more pronounced – around 60% on average. All this indicate the positive

Substitutions between energy and labor?

As it has been already mentioned, Bernd and Wood observed positive and significant substitution between energy and labor on the sample of US firms. We apply similar technique to test the existence of this substitution effect in Russian firms over the period of 1998-2002. For estimation we exploit translog cost function. Lacking reliable data on capital stock we use only two factors of production - electricity and labor.

Translog cost function is chosen because this functional form does not places any a priori restrictions on the Allen partial elasticities of substitution. Assuming symmetry and constant return to scale for our two factor model the cost function can be presented in the following way:

$$\ln G = \ln \alpha_0 + \ln Y + \alpha_L \ln P_L + \alpha_E \ln P_E + \frac{1}{2}\gamma_{LL}(\ln P_L)^2 + \frac{1}{2}\gamma_{EE}(\ln P_E)^2 + \gamma_{LE} \ln P_L \ln P_E,$$

where G stands for costs of production output in amount of Y, and P_L, P_E are prices of inputs labor and electricity respectively.

Under perfect competition on factor markets assumption cost minimization provides us with the following demand functions for inputs

$$M_L = \frac{P_L L}{G} = \alpha_L + \gamma_{LL} \ln P_L + \gamma_{LE} \ln P_E \quad (3)$$

$$M_E = \frac{P_E L}{G} = \alpha_E + \gamma_{EE} \ln P_E + \gamma_{LE} \ln P_L \quad (4)$$

where M_i is the cost share of factor i in total costs G.

Uzawa (1962) has shown that in this case the Allen partial elasticity of substitution between two factors i and j could be derived as:

$$\sigma_{ij} = \frac{GG_{ij}}{G_i G_j}$$

where $G_i = \frac{\partial G}{\partial P_i}$ is a partial derivative by the factor price, $G_{ij} = \frac{\partial^2 G}{\partial P_i \partial P_j}$ is mixed derivative by prices of two factors.

For the translog cost function the Allen partial elasticities of substitution could be presented in the following way:

$$\sigma_{ii} = \frac{\gamma_{ii} + M_i^2 - M_i}{M_i^2}, \ i = L, E \quad (5)$$

$$\sigma_{ij} = \frac{\gamma_{ij} + M_i M_j}{M_i M_j}, \ i, j = L, E, \ i \neq j \quad (6)$$

Allen (1938) showed that the Allen partial elasticities of substitution are related to the price elasticities of demand for factors of production $E_{ij} = \frac{\partial X_i}{\partial P_j}$ in the following way:

$$E_{ij} = M_j \sigma_{ij} \quad (7)$$

In what follows we apply the above methodology to Russian data.

Comparing some average statistics of Russian firms over the period 1998-2002 with relevant statistics of US firs for the period 1947-1975 we find close similarities. The corresponding figures are presented in table 13.

Table 13. Average cost shares of labor and electricity

	In the sample	In the US data[9]
Labor cost	0,22	0,24-0,28
Electricity cost	0,05	0,04-0,05

[9] Data on US firms (1947-1971) are from Berndt, Wood (1975). Over twenty five years the average cost shares in US industrial firms have been quite stable.

In order to estimate equations (3) and (4) on Russian firms' data we rely on size-dependent tariffs for electricity while average wage calculated as labor cost divided to the number of employees for each individual firm is used as labor price. There are 4063 observations in the sub sample.

The results of estimations of equations (3) and (4) are presented in the table 14.

Table 14. Parameter estimates of translog cost function

Parameter	Estimates
γ_{LL}	-0,009 **
	(-3.26)
γ_{LE}	-0.005 **
	(-4.55)
γ_{EE}	0,019 **
	(7.36)

*-5%, ** - 1% level of significance, t-statistics in parenthesis

Now putting the estimates from table 14 into relations (5) and (6) we calculate the Allen partial elasticities of substitution for each firm. Then applying formula (7) we can compute the price elasticities of demand for production factors. The average elasticities calculated for our sample are presented in table15 along with estimations for US firms.

Table 15. Allen and price elasticities

		In our sample	In US data[10]
Allen partial elasticities of substitutions	σ_{LL}	-5.12	-1.79
	σ_{LE}	-0.06	0.61
	σ_{EE}	-6.89	-10.69
Estimated price elasticities of demand	E_{LL}	-0.82	-0.47
	E_{EL}	-0.07	0.16-0.20
	E_{LE}	0.025	0.03
	E_{EE}	-0.30	-0.47 — -0.49

The estimated own price elasticity of demand for electricity is generally consistent with our previous findings. As for substitution possibilities between labor and electricity we do not find unambiguous results. First, the negative sign of E_{EL} indicates that as the labor price increases (and the demand for labor declines) then the demand for electricity will also decreases. So labor and electricity in this case are rather complementary inputs rather than substitutes. On the other hand, the positive sign of E_{LE} indicates the possibility of substitution between labor and electricity consumption as electricity price changes. It seems to be that missing the capital from analysis is substantial drawback of our analysis since over the period of time under consideration we observe a substantial growth of output along with increased investments which could influence both labor and electricity demand.

[10] These figures have been obtained by Berndt, Wood (1975).

5. Conclusions

In this paper we analyze the dynamics of industrial electricity consumption in Russia during five years (1998—2002). The data indicates that on average over these five years the industrial electricity consumption increases by 30%. We explain this by both growth of production and the relative decline in electricity price. Furthermore, on average electricity consumption per 1 ruble of real output decreased. At the same time we have found a substantial negative impact of new investments in fixed assets on electricity intensity of output. We interpret these results as an evidence of the decline in electricity intensity of Russian industrial production.

By applying two models of electricity demand to Russian data we estimate price elasticity of electricity demand to be in interval -0.2 -- -0.4 which is close to estimations of elasticities for US and European firms.

As far as substitution possibilities between labor and electricity in production are concerned we did not get the reliable result. For more accurate conclusions in this respect we need to take into account more factors of production which is impossible to do base on our dataset.

6. References

Berndt E., Wood D. Technology, Prices and the Derived Demand for Energy, Review of Economics and Statistics, 57(3), 1975.

Bue Bjorner Th., Togeby M., Christensen J. Industrial Energy Demand – a Micro Panel Data Analysis, AKF Forlaget, Denmark, 1998.

Allen, R.G.D. (1938) *Mathematical Analysis for Economists*. London, p.503—509.

Uzawa, H. (1962), “Production Functions with Constant Elasticities of Substitution”. *Review of Economic Studies*, Oct. 1962, p. 291—299.

Solodnikova, K. (2003), “Estimation of Energy Demand Elasticity in Russia.” NES. Master Thesis.

Maitak, O. (2003), “Estimation of the residential electricity demand function in Russia.” NES. Master Thesis.