Using Panzar-Rosse Model for Selecting Electricity Markets Regulation Tools: the Case of Russian Wholesale Electricity Market

Tatiana Gass, National Research University Higher School of Economics, +79161221137, tgass@hse.ru
Sergey Kechin, Institute for Economics and Regulation of Natural Monopolies, skechin@hse.ru
Ilya Dolmatov, Institute for Economics and Regulation of Natural Monopolies, idolmatov@hse.ru

Overview

Understanding the features and competition level of the market is necessary for smart economic policy at any market. Competition level influences on market interaction and on regulatory practices.

We considered a part of wholesale electricity market, where electrical energy trades. This part of wholesale market divided into free flow areas (FFA), inside FFA electrical energy can be transferred in almost any volumes, between FFAs electricity transmission volume is limited. We supposed that competition level vary among FFAs and the same regulation tolls produce different results. Testing this hypothesis included 2 stages. At the first stage we shared all FFAs into two groups by their competition levels using Panzar-Rosse model and then, at the second stage, we analysed how price determinants affect prices in each group.

We find that price influencing factors act different at FFA with different competition levels. So, it is showed necessity to finer tuning of policy tools at different parts of wholesale electricity markets to achieve the same overall market goals. We understood that situation with different competition levels at the parts of markets had origins in path dependence and easy resolution is impossible. Liberalization process continues at electric power sector and government should oversee nowadays condition of this sector, because of high significance and long-time investment process at industry.

Electricity at Russia consists of two goods – electric power and electric energy, all of them can be sold at wholesale or retail market, in our paper we consider the electric energy (further calling it electricity) and wholesale market. Electricity can be sold or bought at day-ahead electric energy market (DAM) for the next day or at balancing market (BM) for today by hourly intervals. Electricity is cheaper at DAM then at BM. Transmission constraints call for dividing market area by free flow areas (FFA), where there are no these constraints. The strongest restrictions are between Europe-Ural (the First Price Zone) and Siberia (the Second Price Zone), Far-Eastern and some other Russian regions are not parts of electricity market. Companies at electricity markets operate at many FFAs.

Our paper considers on day-ahead electricity market, as most competitive part of industry. The goal of this paper is twofold. First of all, we estimate competition level at the day-ahead market (DAM) on the whole and on their parts, free flow areas (FFA). For this task we use the Panzar-Rosse model, as we know, this model wasn't used for Russia wholesale electricity market before this research. At this stage we break down all FFA into 2 categories by their competition level. Secondly, we make an estimate of price' determinants for different types of FFA and mention different effects of the same variables.

Literature review

Nowadays Panzar-Rosse model applies at different sectors, the better half of researchers analyses banking and insurance sectors. The main result of this model is competition level (H-stat) of the industry or its part. The widespread use of the model in the banking sector is associated with the availability of cost data, in other industries complete accounting reports are less available, but it won't stop researchers. Sergeeva (2016) used Panzar-Rosse model to analyze competition at the Russian University Market. Hirata (2018) expressed H-stat by using the demand elasticities in container liner shipping market. Li and Marinc (2015) explored competition in the clearing and settlement industry using additional components to Panzar-Rosse model, such as mergers, technological development and others. Dividing industry or market into parts allows getting interesting results, for example, Mamontov (2010) showed that large and medium banks are in a state close to perfect competition, while small and ultra-small banks are in a state of monopolistic competition.

Competition level (H-stat) uses as dependent variable and as independent variable in different papers. Classical model operates with product and factor prices from companies' reports, but there are other methods of cost estimate in some papers. For example, Alhassan and Biekre (2016) used SFA-method for cost prediction, Nikolaev and others (2015) used prices at regional level of aggregation. We also use price information from official statistical services not for company's information.

Russian wholesale electricity market consists of two parts: Europe and Ural (the First Price Zone) and Siberia (the Second Price Zone). Federal Antimonopoly Service of Russian Federation (The FAS Russia) measured the level of concentration (CR) in the wholesale electricity and capacity market and defined competition level at First Price Zone as low and at Second Price Zone as moderate (2020). The FAS Russia measured the level of concentration (CR) in the wholesale electricity and capacity market by the volume of electricity production and defined competition level at First Price Zone as moderate and at Second Price Zone as

high (2020). These results corresponds with results of the Association "NP Market Council" (2019), the shares of the three largest companies (CR3) are 55% at First Price Zone and 80% at Second one, the Herfindahl-Hirschman indexes (HHI) are 1298 and 2690 respectively. But we can't find any survey which explored competition level at the free-flow areas or their differentiation by competition levels.

Our research has two hypotheses: first one is about competition level; the second one is about price factors. The first one is "the level of competition at different FFAs in One Price Zone is not equal". The second one is "regulation instruments affect prices in different ways at FFAs with different competition levels". We use econometric tools to test them. More about our methods in the next part of the paper, other parts of paper are divided into two parts, one part for one hypothesis.

Methods

Part 1 – Competition level

Panzar-Rosse model for banking sector can be written as:

$$\ln(II_{i,t}) = \lambda \quad + \beta * \mathrm{FIP}_{i,t} + \gamma * \mathrm{BSF}_{i,t} + \varepsilon_{it},$$

where

II – interest income,

FIP – factor input prices (block of variables),

BSF – bank specific factors (block of variables).

The sum of β is H-stat, if H-stat is negative it means absence of competition, if H-stat is equal to one it means perfect competition.

In the original, analysis of the level of competition requires data on individual firms; however, power suppliers operate at many FFAs and authors can't divide data for each FFA by firm's information, so information was used by FFAs' levels from Russian statistical service and Trading System Administrator of wholesale electricity market (ATS). This approach does not allow us to estimate H-stat with high accuracy, but it allows us to draw a conclusion about the degree of competition in the market and check our hypotheses.

An additional limitation is the lack of data on prices for all regions of Russia for many factors of production, however, price indices for these factors are presented in the context necessary for analysis. It is known that the distribution of many financial indicators, including prices, will be normal if we take their logarithms instead of the dummy values of indicators, therefore, the logarithms of prices are used in the work. In addition, it is known that the difference of two normal distributions is a normal distribution, so the model can be evaluated in terms of the differences. According to the rules of subtraction of logarithms, the difference of logarithms is the logarithm of the ratio of their arguments, thus, from prices of specific goods, you can go to price indices of these goods if the model is calculated in differences.

Our model is applied official information by 20 FFAs by each month for 3 years from Trading System Administrator of wholesale electricity market (ATS). Hourly data aggregates to day level and then day data aggregates to month data. Factor prices take out Federal State Statistic Service, regional data aggregates to FFAs level. FFAs include from 1 to 18 regions.

ATS provides buy and sell prices, we use buy prices.

The model for DAM price can be represented as follows:

$$\log(P_{i,t}) = \beta_0 + \sum_{l=1}^{k} \beta_l * \log(x_{l.i,t}) + \sum_{j=1}^{m} \gamma_j * \log(z_{j,i,t}) + \varepsilon,$$

where:

P – DAM-price,

x_l – price of factor l,

zj – market related variable j,

H-stat is equal to sum of βl form 1 to k.

The difference model is as follows:

$$\log(P_{i,t}) - \log(P_{i,t-1}) = \sum_{l=1}^{k} \beta_l * \log(x_{l,i,t}) - \sum_{l=1}^{k} \beta_l * \log(x_{l,i,t-1}) + \sum_{j=1}^{m} \gamma_j * \log(z_{j,i,t}) - \sum_{j=1}^{m} \gamma_j * \log(z_{j,i,t-1}) + \varepsilon$$

or

$$\log\left(\frac{P_{i,t}}{P_{i,t-1}}\right) = \sum_{l=1}^{k} \beta_l * \log\left(\frac{x_{l.i,t}}{x_{l,i,t-1}}\right) + \sum_{j=1}^{m} \gamma_j * \log\left(\frac{z_{j,i,t}}{z_{j,i,t-1}}\right) + \varepsilon.$$

For the model in differences, all variables, except for dummy, were transferred to indices reflecting the change in the variable over the period. The use of dummy in the model with differences is necessary to consider the generation structure in the FFAs when calculating the model based on the DAM as a whole. This model is calculated using regression with fixed effects on panel data, because it is important to separate the effect of the

presence of a nuclear power plant (NPP) or hydroelectric power plant (HPP) in the area from the features of a particular FFA.

The characteristics of the market in the model are the price and non-price parts of supply and demand, the ratio of demand to the non-price part of supply, and the ratio of supply and demand. We also used dummy variables that reflect the structure of generation in the region and the period of the year.

Part 2 – Price factors

Our assumptions regarding the dependence of the price of DAM on other factors can be presented in the form of the following formula:

$$P_t = \alpha * P_{t-1}^{\eta} * (x_t/x_{t-1})^{\beta} * (z_t/z_{t-1})^{\gamma} * e^{\gamma * z_t} * P_{t-12}^{\mu} * cross_t^{\lambda} * e^{\lambda * cross_t + \varepsilon}$$

where

P – DAM-price for buyers,

x – price of factors,

z – market related variables,

cross – cross-subsidization variables.

It should be noted that to simplify the formula, the factors *x, z, cross* represent a block of variables, each variable of which has its own coefficient.

In Russia electricity prices for households are regulated and lower than for industry and other users (in 2020 prices for households was 66% of prices for other users except households and 79% of prices for industry), so cross-subsidization variables reflect structure of sales at FFA.

The better results produce model in logarithms.

After taking the logarithm, the model takes the form:

$$\log(P_t) = \alpha + \eta * \log(P_{t-1}) + \beta * \log(x_t/x_{t-1}) + \gamma * \log(z_t/z_{t-1})$$

$$+\gamma * (z_t) + \mu * \log(P_{t-12}) + \lambda * \log(cross_t) + \lambda * cross_t + \varepsilon$$

If we have statistically differently coefficients β and γ for FFAs with different competition levels, then price factor for different competition level FFA are not the same. So, market regulation can influence differently at FFAs with different competition levels.

Additionally, we analyse the similar model for retail market, but we use the DAM price instead prices of past periods, other variables are the same.

$$\log(Pretail_t) = \alpha + \eta * \log(P_t) + \beta * \log(x_t/x_{t-1}) + \gamma * \log(z_t/z_{t-1})$$

$$+\gamma * (z_t) + \lambda * \log(cross_t) + \lambda * cross_t + \varepsilon$$

Where

Pretail – end-user price,

P – DAM-price for buyers,

x – price of factors,

z – market related variables,

cross – cross-subsidization variables.

This model has also been analyzed by two types of FFAs separately. If we have statistically differently coefficients β and γ for FFAs with different competition levels, then market regulation can influence differently at parts of retail market too. The part of retail market analysis isn't finish yet, but preliminary results are interesting.

Empirical results

Part 1 – Competition level

The first step is to check all market to choose model variables and test the model. The second step is to analyze different FFA with chosen model and to divide them into two groups with different competition levels.

On DAM producers can consider only fuel prices, but we also use other factors (wages in energy sector or rest (spare parts, tools and accessories)) for catching regional price differences. The results for the whole market model are presented in table 1.

Table 1. The whole market model results.

Independent Variables	Coefficient (standard error)
NPP	-0.011* (0.006)
HPP	-0.007 (0.005)
Non-Price Supply and Import	0.063*** (0.018)
Price Supply	0.039** (0.013)
Demand	-0.133*** (0.036)
Non-Price Demand	0.043** (0.021)
Ratio of Demand and Supply	0.082** (0.033)
Coal price	0.527** (0.166)
Fuel oil price	-0.220** (0.084)
Rest price	0.358** (0.162)
_cons	0.491 (0.470)
Prob > F (u_i=0)	0.991
Corr (u_i;Xb)	-0.533
R^2 within R^2 between R^2 overall	0.094 0.025 0.066
Prob > F(10,508)	0.000

*Note: * Statistically significantly different from zero at the 10% level based on a two-tail test.*

*** Statistically significantly different from zero at the 5% level based on a two-tail test.*

**** Statistically significantly different from zero at the 1% level based on a two-tail test.*

Source: T. Gass and et al. (2020)

There are no gas prices in the resulting model; we associate this with the high correlation between gas and oil products prices, which are presented in the model. Another explanation of gas prices' absence is merit order pricing. Gas-fired stations are less likely to become the producers with the highest costs of energy, because electric energy production costs more at coal and diesel power stations.

H-stat is sum of coefficients of the coal price, the fuel oil price and the rest price. H-stat for DAM is 0.31 or 0.66, it is higher when regional price difference is considered. Thus, DAM is moderately competitive. Our result is close to other competition estimations for DAM.

When analysing such regression for individual FFAs, the dummy variables of the presence of NPP and HPP in the region were not used. The model was good for 16 of 20 FFAs and individual regressions were used only for three FFAs, since the general form of regressions gave insufficiently reliable results (the significance level of the model is generally below 10%). No regressions were found for only one FFA. Perhaps this is due to the fact that all TPPs in the region are owned by one firm. Due to the lack of connection between DAM prices and costs, it was decided to classify this zone as an FFA with a negative H-stat value.

At the first pricing zone 10 of 15 FFA are limited competitive zones; at the second price zone 2 of 5 FFA are limited competitive zones. So, First Pricing zone is more competitive than Second One. H-stat for FFAs ranges from -1.00 to 0.52, which means that competitive level is higher for DAM as a whole (H-stat is 0.31-0.66).

Table 2 demonstrates descriptive statistics for different types of FFA. There are more power plants and gas-fired power plants in limited competitive zones, prices are also higher at this type of FFA.

Table 2. Descriptive statistics of DAM and FFAs.

	Day-Ahead Market	Limited competitive zones	Weak competitive zones
	mean (minimum-maximum)		
Consumer Price	1 182.22 (550.75; 2 135.83)	1 290.16 (847.45; 2 135.83)	1 020.32 (550.75; 1 569.76)
Number of power plants, except NPP and HPP	8.50 (0; 44)	10.33 (0; 44)	5.75 (1; 19)
Share of gas-fired power plants	0.64 (0; 1)	0.78 (0.01; 1)	0.44 (0; 1)
Ratio of Demand and Supply	0.74 (0; 0.99)	0.75 (0; 0.99)	0.73 (0.00; 0.99)
Share of weak competitive zones	0.40	-	-

Source: T. Gass and et al. (2020)

Part 2 – Price factors

The next step of our analysis is to compare the price factors of two types of FFAs. We make it twice: first time for DAM prices and second time for retail prices. Cross-subsidization variables are (1) cross-subsidization volume for 1 kWh for non-residents, (2) ratio of resident and non-resident prices, (3) logarithm ratio of resident and non-resident prices, (4) logarithm change in ratio of resident and non-resident prices. Supply and demand at DAM were divided into price and non-price parts of supply and demand. Also changes in manufacturing production and electricity, gas, steam and water supply services production are introduced into the model. Table 3 shows the results for DAM-prices and table 4 shows the preliminary results for end-user prices.

Table 3. Price-factor models for DAM prices

	Whole Market Model	Limited competitive FFA Model	Weak competitive FFA Model
Purchase price last month	0.579***	0.498***	0.609***
Purchase price last year	0.208*	0.329***	0.271
Rest	0.614*	1.025***	-
Cross-subsidization1	0.121***	0.159***	-
Cross-subsidization2	-0.229***	-	-
Cross-subsidization3	1.368***	1.419***	-
Cross-subsidization4	-4.449***	-4.873***	-0.609*
Income by man (change)	-0.025***	-0.040***	-
Income by man	-	-1.24e-06	-1.24e-06**
Index of manufactory's production	0.098**	0.124***	0.270**
Climate (change)	0.904*	-	-
Climate	-	0.002***	-0.001
Fuel price	-	-0.706***	-
Coal price	-	0.024*	1.260**
IPC	-	-	7.592
wages	-	-	0.336**
Demand	-0.096	-	-
Ratio of Demand and Supply	0.095	-	-
Non-price part of Supply	0.094**	0.035	-
Price part of Supply	0.053*	-	-
_cons	5.496**	8.149***	-15.989*
Sigma_u	0.074	0.059	0.073
Sigma e	0.061	0.050	0.070
Rho	0.595	0.583	0.521
Prob > F (u_i=0)	0.0000	0.0001	0.0443
Corr (u_i;Xb)	0.559	0.734	-0.065
R^2 within R^2 between R^2 overall	0.525 0.915 0.841	0.594 0.965 0.895	0.540 0.668 0.615
Prob > F	0.0000	0.0000	0.0000

Table 4. Price-factor models for end user prices

	Whole Market Model	Limited competitive FFA Model	Weak competitive FFA Model
Price Buy at DAM	0.075** (0.035)	0.116** (0.050)	0.030 (0.055)
Non-Price Supply and Import	-	-	-
Price Supply	-0.022** (0.009)	-0.021 (0.015)	-0.014 (0.013)
Demand	-0.030* (0.015)	-0.035** (0.017)	-0.013 (0.036)
Non-Price Demand	0.026* (0.015)	0.030* (0.017)	0.009 (0.035)
Ratio of Demand and Supply	-	-	-
Coal price	-	-	-
Fuel oil price	0.146** (0.066)	0.062 (0.090)	0.222** (0.104)
rest	0.448*** (0.013)	0.363** (0.160)	0.562** (0.238)
wages	0.036 (0.024)	0.024 (0.028)	0.106** (0.052)
Cross-subsidization4	0.986*** (0.120)	0.900*** (0.152)	1.140*** (0.220)
Index of manufactory's production	0.056*** (0.018)	0.033 (0.020)	0.158*** (0.045)
Index of electricity, gas. water production	-0.050*** (0.018)	-0.030 (0.021)	-0.091** (0.036)
Climate (change)	-0.949*** (0.119)	-0.862*** (0.151)	-1.137*** (0.219)
_cons	0.555* (0295)	0.852** (0.380)	-0.004 (0.509)
R^2 overall	0.1582	0.1549	0.2074
Prob > F	0.0000	0.0000	0.0000

Analysis of the model's indicators shows that:

- the DAM price depends on the price of the previous month and, to a lesser extent, on the price of the previous year;
- there is a weak positive dependence on the industrial production index and even less negative dependence on changes in household income;
- the impact of cross-subsidization appears to be significant for all accounting options;
- the coefficients of demand and the ratio of demand to supply have almost identical values, with the exception of the sign at the coefficient itself, but their exclusion from the model leads to a significant increase in the correlation of the residuals of the model with the variables and leads to a drop in the model's quality;
- the ratio of the parameters of the non-price and the price parts of supply shows that the non-price part of supply has a greater influence on the prices.

This looks logical if we consider the specifics of the DAM market, in which the non-price part of the electricity supply through the FFA is primarily satisfied. Refusal to consider one of the parameters of the market structure leads to a deterioration of the model and refusal to consider all factors of supply and demand in the market, which distorts the influence of other variables.

Comparison of the two models shows the best quality for the model for weak competition FFAs, the correlation of the variables with the residuals is significantly lower, although in terms of the explanatory ability R^2 it is inferior to the model for limited competition FFAs.

In areas with weak competition an increase in the price supply leads to an increase in the DAM price; for limited competition FFAs, it does not appear in the regression at all. At the same time, an increase in non-price supply for zones with limited competition leads to a slight increase in prices, but the significance of this coefficient is low, but its exclusion from the model leads to a significant drop in the quality of the model as a whole. In the conditions of bids satisfaction, the principle is first satisfaction of the non-price part of the demand. That is, the larger the non-price supply, the less demand remains for price bids, that is, the sector of competition in the market narrows. Quite strange at first glance, the results that in more competitive FFAs a non-price part of supply is significant, and in less competitive ones - a price part of supply, may indicate the orientation of the "monopolist" towards small competitors in less competitive zones. At the same time, an increase in the share of non-price supply indicates a decrease in competition, which in theory should lead to an increase in prices, which reflects a positive coefficient at the variable of non-price supply.

The coefficient for the manufactory's production index is higher for weak competition FFAs, for both types of zones it is positive: with an increase in production, the DAM price also increases. From the point of view of economic theory, it means an increase in demand for a product, which leads to an increase in its price. At the same time, for monopoly markets, an increase in demand will lead to a greater increase in prices due to the fact that the monopolist interacts not with demand, but with the marginal revenue curve, which, with linear

demand for a product, turns out to be twice as steep. The parameter value for the production index for weak competition FFAs is 2.25 times higher than for limited competition FFAs.

Regulator can change decision about market rules, for example, determine power station to non-price and price parts of supply or prescribe supplier of last resort which sold electricity for households to buy a part of electricity as a price part of demand. Price parts of supply and demand are very important to competition level at the market and regulator can change rules of definition these parts of market. Cross-subsidization of population is very hot question in Russia, but the most significant variable is growth of cross-subsidization. And in this part government can influence, slowdown in this growth will lead to more decline at limited competitive FFAs at retail market, than at weak competitive FFAs.

For end-user prices market structure are less significant. Cross-subsidization is important only in terms of its changes. But manufacturing output is significant for weak competition areas and coefficient is higher than for a whole market. More over connection between retail and DAM prices is closer for limited competitive FFAs, and response for demand at DAM is higher for these areas. Note that regression at retail market is pooled, because significance levels of fixed-effect model for all regression are close to 1.

It's an intresting result, that DAM-prices are not affect the end-user prices. We suppose continue to analyse this fact further.

So, we can assert that regulation tools influence in different ways for FFAs with weak and limited competition levels. Also, weak competition in the DAM is manifested in a stronger influence of regulated components on the retail price. Conversely, limited competition on the DAM can lead to greater impact of wholesale market price signals to retail prices of electricity.

Conclusions

We demonstrated applicability of Panzar-Rosse model for Russia wholesale electricity market and divided it into two FFAs types. DAM is limited competitive market. At the First Pricing zone 10 of 15 FFAs have limited competition level; at the Second Pricing zone at 2 of 5 FFAs competition is limited, other FFAs are weak competition areas. Price factors for these FFAs are also different.

Price influencing factors act different at FFAs with different competition levels. The degree of costs influence differs by areas' type, as well as relevance of costs differs. For example, wages influence on price only at limited competitive FFAs. Cross-subsidy components (which correlated with non-price part of demand) at electricity prices influences at both FFAs types, but their influence differ. So, the same regulation tool may lead to different results. For example, an increase in share of non-price offers (hydroelectric power station or cogeneration plants) will reduce wholesale prices at weak competition FFAs and increase wholesale prices at limited competition FFAs.

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