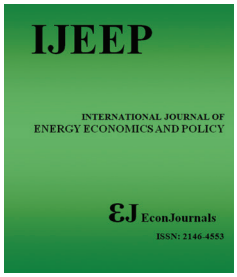


International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2020, 10(2), 265-275.

Consumer Surplus Changing in the Transition from State Natural Monopoly to the Competitive Market in the Electricity Sector in the Developing Countries: Azerbaijan Case

Mayis Gulali Gulaliyev[1]*, Gulshen Zahidqizi Yuzbashiyeva[1], Gulnara Vaqifqizi Mamedova[1], Samira Tahmazqizi Abasova[2], Fariz Rafiq Salahov[1], Ramil Ramiz Askerov[1]

[1]Institute of Economics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan, [2]Azerbaijan State University of Economics, Baku, Azerbaijan, *Email: mayis_gulaliyev@yahoo.com

Received: 28 September 2019 **Accepted:** 04 January 2020 **DOI:** https://doi.org/10.32479/ijeep.8909

ABSTRACT

The objectives of the study are to analyze changes in consumer surplus and protect the social interest of poor households (HHs) in the transition from a state monopoly over the electricity sector to the market. For this purpose, the volume of HH electricity consumption by various incomes was calculated, the electricity demand function of HHs and the marginal cost of generating electricity were constructed. A methodology is given for calculating the electricity demand function for HHs and prices in an equilibrium market. The consumer surplus and its change are calculated. As well as there are given some recommendations to reduce the social burden for certain HH groups while raising prices in the transition from a monopoly to the market, and the amount for the state subsidy for poor HHs.

Keywords: Consumer Surplus, Producer Surplus, Electric Power Sector, Pricing, Marginal Cost, Average Costs
JEL Classifications: D42, L51

1. INTRODUCTION

In many developing countries, especially in the countries of the former Soviet Union, including Azerbaijan, the entire electric power system, including production, transmission, distribution and sale, is under state monopoly. All electricity companies are state owned, and the price of electricity is determined by the Tariff Council under the government (TCRA). As usual, the state as a natural monopolist, unlike a monopolist in the market, keeps prices below market to protect the interests of the population. At the same time, producer losses for low prices are covered from the state budget. This is due to government policies to protect household (HH) interests. Most states where there is a state monopoly in the electricity sector, the state sets prices below real to reduce the cost of electricity for businesses. Such government intervention in pricing reduces energy costs and stimulates the actions of small and medium-sized businesses, but reduces the income of electricity production companies. In such situations, demand volume usually unreasonably increases and the quality of power supply decreases.

Related with an increasing of incomes and market thinking of the population, as well as in connection with the state liberalization policy in recent years, a need has arisen for a transition from a natural state monopoly in the electricity sector to market relations in the countries of the former Soviet Union, including in Azerbaijan. Privatization of some fields of the electricity sector, for example, production and retail sales, is strategic vision of many developing countries, e.g., of Azerbaijan (SRM, 2016). At the initial stage of privatization, there is a high probability for price increasing in this strategically important sector and this can lead to social problems for HHs, as well as lead to changes of the business environment for small and medium-sized businesses. Therefore, there is a need

to calculate the electricity demand function for HHs and industry, as well as the marginal cost of the main producers to estimate the amount of change in the consumer surplus and producer surplus in the transition from a natural monopoly to the market.

Purpose of the investigation is to assess the level of possible electricity price changes due to the transition from a natural state monopoly to a perfect market to mitigate the loss of consumer surplus.

To achieve this goal, the following tasks were set: (1) assessment of electricity demand volume dynamics relationship with HHs' income and expenditure for electricity; (2) determine the structure of costs and revenues for the production of electricity in Azerbaijan; (3) determination of the function of general and average costs for the Azerbaijan Thermal Power Plant (ATPP) and for the "Azerenerji" OJSC; (4) determining the demand function for HHs and industry; (5) determining the function of marginal cost for some power plants; (6) determining the elasticity of electricity demand at prices.

ATPP and "Azerenerji" OJSC were taken as case study of the research. Similar calculations can be made for other electricity power plants of any countries.

The main hypothesis: (1) The price of electricity under a state natural monopoly and in the absence of an electricity market is lower than in a perfect market; (2) As usual the state regulates the price of electricity below the market price to reduce the social burden of HHs and to stimulate small and medium businesses; (3) in the transition process from a natural state monopoly to the perfect market there are expected an increasing of electricity prices and decreasing of consumer surplus in short run.

2. LITERATURE REVIEW

An analysis of the theoretical and empirical literature on the electricity market confirms that most of these models are applicable in liberal markets. For example, volatility models, such as Auto Regressive Conditional Heteroscedasticity (ARCH), General ARCH, Multidimensional GARCH, are suitable for describing volatility in the heteroscedasticity price structure. There were studied some issues on autoregressive models (Misiorek et al., 2006; Guthrie and Videbeck, 2002; Popova, 2004), as well as transition switching and mode switching models (Cartea and Figueroa, 2005), and volatility models (Serletis and Shahmoradi, 2006), the problems of electricity pricing in the monopolistic market (Julian and Edward, 1983; Juan and Alejandro, 2010), etc. Studies such as determining the demand function for electricity for HHs or for industry are often found in the economic literature (e.g., Madhu and Narasimha, 2009; Seung-Hoon et al., 2007; Naceur et al., 2018) and studies such as price forecasting (Rafał, 2014). In the economic literature, various models are proposed for determining the price of electricity in a market and natural monopolies (e.g., Greer, 2011; Holmberg and Newbery, 2010). But the problems of consumer surplus losses in the transition process from a natural state monopoly to a market have not been studied much. But this problem is typical mainly for developing countries, especially for countries with economies in transition, where the electricity sector is state-owned, and the price of electricity is set by the state bodies.

3. METHODOLOGY

Electricity Demand in HHs is generated by maximizing benefits and minimizing costs. The amount of electricity used in HHs may depend on several determinants, including the cost of electricity, total HH income, the number of HH members, and the size of living space and other determinants. Given these indicators, the electricity demand in HHs can be simplistically expressed as:

$$ElecCons=F\ (Price,...I,\ HN,\ DS,\ G,\ PW) \quad (1)$$

Here, the *ElecCons* is the amount of electricity consumed in HHs, *Price* is the price of electricity, *Income* is the income of the HH, *HN* is the number of people in the HH, *DS* is the size of the living space in the HH, *G* is the energy products that can replace electricity, PW is the potential production capacity of power plants operating in the country. We can take as "*G*" natural gas, thermal energy (for the urban population) and wood energy (for the rural population). The key reason for incorporating *PW* into the empirical model that the *EC* depends on is that demand in the electricity market depends to some extent on supply. If electricity is not produced or is not produced in the required volume, the volume of demand also changes. The list of such determinants in the economic literature is different. For example, you can consider the size of the living space on which the HH is located, or the regional characteristics of the use of electricity as dummy indicators. The price of gas, which can replace electricity, can also be included in the demand function. When using electricity, models are also proposed that take into account the age and education of HH members. When you include another energy sources in the model, e.g.,natural gas, it is important to consider that it "replaces" electricity or "supplements" it.

In many developing countries, including in Azerbaijan, there are several distinctive features of the use of electricity in HHs, and we must consider when studying:

1. The price of electricity does not depend on the regions within countries
2. Electricity price is constant for any consumers, i.e., for HHs and industry. Or electricity prices have two-three levels, depending on the volume of use and are determined by the state. For example, in Azerbaijan electricity prices have two levels: if a HH uses electricity up to 250 kWh/month, the tariff will be 0.07 (manat[1]/1 kWh) and 0.11 (manat/1 kWh) if electricity consumption exceeds 250 kWh/month. Until 2016, electricity prices did not depend on the volume of use.

Since HH incomes in Azerbaijan are very different, and income inequality in the country is quite large (Gulaliyev et al., 2018), it is more appropriate to calculate the electricity demand in accordance with each income group. Since the difference in the elasticity of demand in price and income is noticeable in such a grouping.

1 1 manat = 0.588 US dolar (according to exchange rate dates from January 2017 to October 2019).

The dependence of the electricity demand function in the country on the average HH income, electricity prices, the share of electricity costs in total costs, consumer price index, consumption of substitute energy sources can be expressed as:

$$ElecCons_t = a_0 + a_1 * Price_t + a_2 * Income_t + a_3 * EXPt + a_4 * CPI_t + a_5 * Gas \ \& \ etc_t + \varepsilon_t \quad (2)$$

In the initial approximation, we consider the dependence of consumption on four indicators - the cost of electricity - $Price_t$, HH income - $Income_t$, the share of electricity costs in total HH spending - EXP_t, and the price index – CPI_t. Although the cost of electricity is stable for a long period, it can affect the volume of demand as a result of changes in the consumer price index. Therefore, it makes sense to look for dependence on this indicator. The study of the dependence of HH demand for electricity on the price index in the country is important, since the price index changes affect the cost structure. As well as the price index can affect the share of electricity in total expenditures and ultimately changes the volume of consumption.

To determine the elasticity of HH electricity consumption by income, we consider the following assumptions:

- Suppose that HHs can be divided into several income groups, and average income and average consumption will be determined without taking into account differences between incomes within each group
- Assume that for each year, the volume of electricity consumption by all HH groups (GHH) consists of two terms: (1) the amount provided for a living wage (LW); (2) the proportion of electricity is proportional to the expenditure remaining after deducting the amount of LW for the given year from HH expenses
- Assume that GHH energy consumption is equal to the multiplication of the number of HHs included in this group by the average HH consumption in the group
- Assume that the demand function for each HH income groups is linear and will be described as P = c - d * Q
- Assume that the coefficient "c" in the demand function for GHH is relevant to the price of electricity that is no longer available for GHH, and at this point consumption stops. Assume that this price has relation with the remainder after deducting the cost of living from the total HH income
- The coefficient "d" in the demand function is related to the amount of electricity used in the country when it is free. Assume that this volume is also not infinite. Since the use of electricity in both winter and summer is associated with certain electrical equipment, and the purchase of these devices requires a certain amount of money, and its quantity is limited for each GHH. In the case when electric energy is free, its consumption cannot exceed the production volumes that relevant to the maximum power of the stations. Therefore, it is possible to accept the maximum consumption of GHH with the lowest income as a share of GHH in production, which relevant to the maximum capacity of the stations.

It is impossible to determine the selling price of electricity by the supply and demand curves in the countries where there is not a competitive market, but a natural state monopoly exists. In such countries, including in Azerbaijan the price of electricity is determined by the tariff council under the government. Given that in a market where there is a state monopoly, and there is no supply curve, we take the cost function as the main one. In the process of research, we will try to establish the cost function, as well as the function of total costs in the production of electricity at major power plants in the country. In determining this function, we will take into account the costs of "Azerenerji" OJSC as a whole. Describing the intersection of marginal costs and the demand function as a possible market price, we compare it with the price set by the Tariff Council in the country. Based on this comparison, we will try to determine the changing of consumer surplus, as well as the changing producer surplus. During the calculations, we must accept some assumptions:

- We will assume that there are no stable costs and all costs are variable. In this case, instead of average stable costs and average variable costs, only "average costs" will be calculated
- When determining costs and average costs, we will prefer to build an approximate relationship based on actual costs for certain years
- Since electricity prices in Azerbaijan are regulated by the state, we will compare current prices with possible market prices when calculating consumer surplus and producer surplus
- Possible market prices will be considered the point at which the marginal cost and the demand are equal
- We will assume that marginal costs and the marginal revenue function are linear
- Taking into account the fact that the main expenses during the operation of thermal power plants after a certain limit are fuel and other costs are relatively low, we describe the function of total costs as quadratic increasing, i.e.,$TC = a * Q^2 + b * Q + c$
- The average cost function for the heat power plant will be expressed as a hyperbolic decreasing function, that is, AC = TC/Q. Here Q is the volume of production.

Necessary dates to calculate the HH electricity demand function in Azerbaijan, including the distribution of HH income and expenses from 2000 to 2017, the structure of income and expenditure per capita in the HHs for the month, the consumption of energy products by HHs (in the natural forms) and other information were obtained from the official website of the State Statistical Committee of the Republic of Azerbaijan (SSCRA, 2018).

4. RESULTS

4.1. The Function of the Volume of Electricity Consumption by One HH

The result obtained from initial studies of regression ratios (2) over the past 10 years between the average HH electricity consumption (*ElecCons*), electricity cost (*Price*), HH income (*Income*), and the share of electricity costs in total costs (*EXP*), the consumer price index (*CPI*) and the volume of consumption of "substitute" energy products (*Gas & etc*) allows us to say that

1. The average volume of electricity consumption by HHs in Azerbaijan does not dependent on the cost of electricity and the consumer price index because of the fact that the electricity price is regulating by state

2. The average volume of electricity consumption by HHs is more dependent on the volume of income and HH's expenditure structure.

Assessment show that the function of the volume of electricity consumption by one HH can be expressed by the model

$$ElecCons = \underset{(702.2023)}{1738.823} + \underset{(0.026113)}{0.247901} * Income + \underset{(7279.007)}{69551.11} * EXP \quad (3)$$

Here we did not take into account dependence on variable *Gas & etc.* This is because the positive dependence of *ElecCons* on *Gas & etc* is largely due to the dependence of *Gas & etc* on *Income*. In other words, there is autocorrelation between *Gas & etc* and *Income* indicators. The negative dependence of *ElecCons* on *Gas & etc* is relatively less than the positive relationship between *Gas & etc* and *Income*. In order to prove the negative relationship between the *ElecCons* and *Gas & etc* indicators, it is necessary to study the effect of gas consumption on HH electricity consumption in a certain income group, i.e., when income does not change.

4.2. Electricity Demand Function for HH Groups (GHH) in Azerbaijan

The strong dependence of the volume of electricity use in HHs on income (3) makes it possible to group the consumption of electricity by HH groups by income and to compile a demand function for each group. HH incomes in Azerbaijan are grouped by different methods.

We can use the income division forms for HHs on quantile, decile and other groups. We will use the SSCAR income distribution for the period 2010-2017. We take this distribution as the basis for comparing income with a living wage. In some cases, for simplicity, we will divide HHs with an income of <180 manat per person from HHs with an income of more than 180 manat. We will study the change in the volume of electricity consumption in HH groups over the past 8 years, dividing them into four groups - with incomes up to 120 manat, 120-150 manat, 150-180 manat, more than 180 manat.

Since the cost of living (MLW) in 2010 was 87 manat, the energy consumption in GHH with a per capita income of 90 manat can be estimated as the "minimum threshold." Given that in the period 2010-2017, the price index in the country grew by 49.5%, we can confidently say that the volume of electricity consumption in 2010 GHH with a per capita income of up to 120 manat will not be less than the volume of consumption in 2017 GHH with a per capita income of 180 manat, and for 2017 the volume of electricity consumption in these groups can be estimated as the "minimum threshold."

In 2010, the range of monthly income for GHH with income less than MLW was 70-90 manat, but in 2017 this range increased to 160 manat. A doubling of the MLW threshold almost happened amid a change in the price index by 49.5%. This had a significant impact on its electricity consumption and demand function by income groups. Since, if we classify the amount of electricity consumed by HHs by GHH income levels, we get the dynamics of the volume of consumption for GHH by year (Table 1).

Assessment show that an increase in total HH income increases electricity consumption (Table 1). The volume of electricity consumption by a HH with a monthly per capita income up to 90 manat is at least 4 times less than HHs whose income exceeds 200 manat. Nevertheless, the volume of consumption for each group decreases every year. There are two main reasons for this.

The decreasing in electricity consumption in Azerbaijan with a stable income, as well as without changing the price of electricity, is associated with an increase in the general price index. An increase in the price index in the overall economy increases GHH expenditures and reduces the share of electricity in total expenditure. With rising prices for other goods and services, the share of electricity in total HH spending decreases. It was also affected by the increase in electricity prices according to a certain scheme in 2016. The second reason is the increase in HHs' use of other energy sources, especially heating systems and the use of natural gas.

As well as assessment show that electricity consumption by more than 121000 HHs in 2010, 19000 HHs in 2011, 35000 HHs in 2013, 149000 HHs in 2014, 44000 HHs in 2015, 24000 HHs in 2016, and 29000 HHs in 2017 is below the level defined for HHs with MLW.

Comparison of the share of GHH with different incomes in electricity consumption shows that there is some correlation between HH incomes and electricity consumption (Table 2). This dependence is largely connected with the fact that, possibility of the purchasing of HH appliances, including refrigerators, washing machines, dishwashers, air conditioners, and water heaters, etc., increasing by HH incomes increasing. Even in multi-storey buildings, the use of electric stoves instead of using gas in the kitchen is most preferable from a safety point of view.

In 2010, HHs group with a monthly 90 manat per capita income consumed 1,226.4 million kWh of electricity in total. This volume means that the electricity consumption by per HH from this HHs group was 1895.6 kWh. However, in the same year, a total of 1,412.24 million kWh of electricity, or 4150.5 kWh of electricity per HH, was consumed in GHH with income of 200 manat and above.

As we mentioned above, the share of HHs electricity expenditure in total HHs expenditure in Azerbaijan over the past 10 years has been downward. In fact, the increase in electricity prices in Azerbaijan over the past 10 years from 0.06 manat to 0.07 manat/1 kWh (and to 0.11 manat/1 kWh for the exceeded part), should not lead to decrease the share of electricity expenditure in total expenses HHs. However, the sharp rise in prices of other goods consumed by HHs, and the rapid increase in the general consumer price index led to some savings in electricity expenditure until a certain threshold. Despite the very low price elasticity of electricity demand, the main reason for the significant reduction in consumption during these years may be related with more economizing character of HHs for electricity consumption. Another important reason is the expansion of gas exploitation in the country. Since, it has become possible to save on electricity by using gas for heating. Utility costs

(electricity, gas and water) per capita in HHs showed an upward trend in the period 2001-2017. In 2013, these expenses were the highest over the past 17 years with a value of 7.7%. In subsequent years, this indicator decreased slightly (Figure 1).

An interesting point regarding the consumption of electricity in GHH in Azerbaijan is that, firstly, with an increase in income, the volume of consumption increases. Secondly, the number of low-income GHH, i.e., which is smaller or has a slight difference from MLW, is steadily declining, and the amount of high-income GHH is increasing. For example, in 2010, the number of HHs with a 200 manat monthly income or more amounted to 7.8% of the total number of HHs, whereas in 2017 their number amounted to 69.3%. This means that in 2017, this particular group was the main consumer of electricity. In markets where prices are liberal, the consumer volume of consumers with such weight plays an important role in determining prices. Thirdly, even in the HHs included in this GHH, average electricity consumption tended to decrease over the period 2010-2017. As mentioned above, the main reason for this is the sharp increase in the consumer price index in those years. A certain increase in HH gas costs among utilities has also led to lower electricity costs. However, we accept the change in the consumer price index as the main reason and assume that, despite the fact that electricity prices are stable during the period 2010-2016, higher prices for other necessary goods led to a decrease in electricity demand in HHs with revenues up to 200 manat. Accepting such a decline as rising electricity prices with similar proportions, we can create a demand function for HHs with different incomes. That is, if the price of 1 kWh of electricity in 2010 was 0.06 manat, and HHs with a monthly income of 120-125 manat consumed 2510.1 kWh of electricity per year, then in case of stability of other prices and an increase in electricity prices by 49, 5% of the consumption will be about 1316.7 kWh. Because there is no other reason to reduce or increase consumer electricity costs. Based on these assumptions, the dependence of electricity expenses on the consumer price index (or adjusted price) for one HH included in GHH with different incomes can be established.

4.3. The Structure of Costs and Revenues for Electricity Production in Azerbaijan

Most of the electricity consumed in Azerbaijan (about 84%) is produced by thermal power plants. Volume of electricity generation by thermal power plants over the past 15 years has changed from 16 to 21 million MWh. In recent years, production has remained stable at around 20 million MWh. Among the thermal power plants in Azerbaijan and in the South Caucasus, the largest

Table 1: Electricity consumption by income for one household (kWh)

p.c. HH's income (manat)	2010	2011	2012	2013	2014	2015	2016	2017
70.1-75.0	1486.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75.1-80.0	1588.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80.1-85.0	1690.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85.1-90.0	1793.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90.1-95.0	1895.6	1639.7	0.0	1416.2	0.0	0.0	0.0	0.0
95.1-100.0	1998.0	1728.3	0.0	1492.7	0.0	0.0	0.0	0.0
100.1-105.0	2100.5	1816.8	1686.8	1569.2	1585.5	0.0	1427.3	0.0
105.1-110.0	2202.9	1905.4	1769.0	1645.7	1662.8	1710.3	1496.9	0.0
110.1-115.0	2305.3	1994.0	1851.3	1722.2	1740.1	1789.8	1566.5	0.0
115.1 -120.0	2407.7	2082.6	1933.5	1798.7	1817.4	1869.3	1636.1	1263.0
120.1-125.0	2510.1	2171.2	2015.8	1875.2	1894.7	1948.9	1705.7	1316.7
125.1-130.0	2612.5	2259.8	2098.0	1951.7	1972.0	2028.4	1775.3	1370.4
130.1-140.0	2766.1	2392.6	2221.4	2066.5	2087.9	2147.6	1879.6	1451.0
140.1-150.0	2970.9	2569.8	2385.8	2219.5	2242.5	2306.7	2018.8	1558.5
150.1-160.0	3175.8	2747.0	2550.3	2372.5	2397.2	2465.7	2158.0	1665.9
160.1-180.0	3483.0	3012.7	2797.1	2602.0	2629.1	2704.2	2366.8	1827.1
180.1-200.0	3892.6	3367.1	3126.0	2908.1	2938.3	3022.3	2645.1	2042.0
200.1 and more	4150.5	3986.3	3700.9	3442.9	3478.6	3578.1	3131.6	2417.5
250 and more	-	6513.8	4523.3	4207.9	4251.6	4373.2	3827.5	2954.7
300 and more	-	-	9261.7	14444.4	14680.3	10333.2	7370.8	4184.6

Calculation of authors

Figure 1: Dynamics of electricity consumption (kWh) in GHH with different incomes

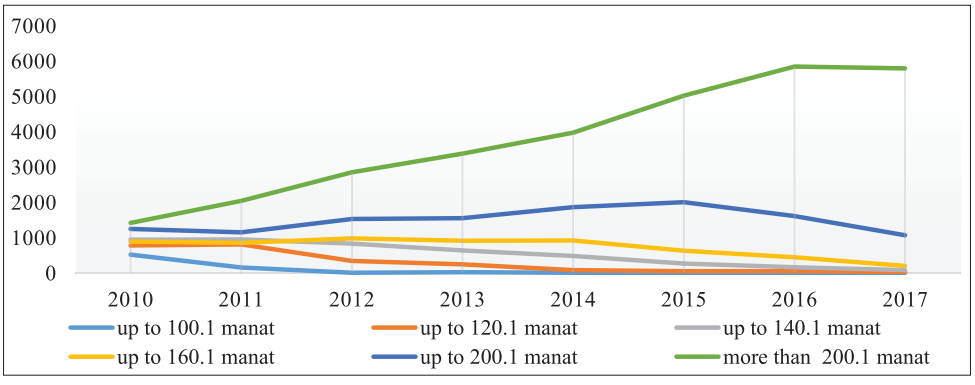


Table 2: Dynamics of electricity consumption by GHH with different incomes (million kWh)

p.c. HH's income (manat)	2010	2011	2012	2013	2014	2015	2016	2017
70.1-75.0	2.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75.1-80.0	51.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80.1-85.0	48.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85.1-90.0	102.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90.1-95.0	134.27	31.79	0.00	5.64	0.00	0.00	0.00	0.00
95.1-100.0	172.13	113.91	0.00	8.91	0.00	0.00	0.00	0.00
100.1-105.0	184.97	165.53	3.31	28.11	6.39	0.00	9.45	0.00
105.1-110.0	206.64	184.69	59.09	36.04	6.71	6.98	9.91	0.00
110.1-115.0	185.35	224.20	138.23	72.00	24.56	14.61	10.37	0.00
115.1-120.0	193.59	226.08	132.97	103.84	40.31	22.89	14.44	21.15
120.1-125.0	225.85	252.53	186.16	111.99	76.41	27.84	18.81	0.00
125.1-130.0	245.07	232.17	185.51	139.87	103.38	53.82	31.33	26.23
130.1-140.0	466.00	459.18	453.94	382.59	298.92	175.34	103.65	48.61
140.1-150.0	455.00	448.35	468.80	455.10	420.54	254.23	169.22	74.58
150.1-160.0	425.57	399.38	506.13	448.69	493.03	372.41	266.57	119.58
160.1-180.0	713.45	654.11	868.36	865.06	986.03	1015.59	725.68	441.53
180.1-200.0	529.09	489.54	657.23	683.13	870.94	980.82	875.21	620.49
200.1 and more	1412.24	772.75	1003.53	1165.15	1367.79	1847.68	1844.36	1694.79
250 and more		1262.19	497.72	510.99	668.70	955.08	1148.22	1237.19
300 and more			1340.02	1698.38	1928.29	2210.60	2844.31	2850.44

Calculation of authors

is the Azerbaijan Thermal Power Station (ATPS). Over the past 5 years, the ATPS produced about 31-35% of the total electricity production and has a total capacity of 2400 megawatts (MW). During 2011-2018 sales of the produced electricity increased from 122 million to 344 million manat. The increase in sales is not sustainable, but the general trend indicates a certain increase. As sales in 2011-2018 changed from $ 242 million (max. in 2014) to $ 109 million (min. 2016). Fluctuations in sales over the years are largely due to changes in production volumes and fluctuations in the dollar-manat exchange rate. As the sales volume increased by 180% in the period 2011-2018, when the volume of final consumption changed by only 33% (i.e. increased from 13 million MWh to 17.6 million MWh).

As the capacity of thermal power plants is used, their costs decrease in accordance with the economies of scale. The main costs in ATPS's cost structure are fuel costs. They make up more than 60% of total costs. Another important part of the costs is depreciation of equipment, maintenance and repair costs, and staff costs. For 2011-2017, these costs, together with fuel costs, accounted for more than 90% of total costs. But in 2018, these costs decreased to 75% of total costs. The prevalence of fuel costs in the main costs of thermal power plants has a significant impact on the price of electricity generated. As while fuel prices, especially oil and gas, are changing in the global market, costs are also changing. If the electricity market is a fully competitive market, changes in fuel prices should immediately reflect on the cost of electricity. However, the decline in oil prices from $ 71.8 in 2006 to $ 53.52 in 2007, an increase to $ 132.82 by 2008, and then a decrease to $ 41 in 2009, again growth until 2014 and a decrease to $ 31 by 2016 did not affect electricity prices in Azerbaijan. The main reasons why such fluctuations in oil prices did not affect electricity prices in Azerbaijan are (1) electricity prices are determined by the state, with compensation by the state for possible losses; (2) Azerbaijan has own oil and gas resources and price for internal market is stable for short run. The losses of consumers and producers are

Figure 2: Dynamics of retail prices (manat) for electricity (base year 2001)

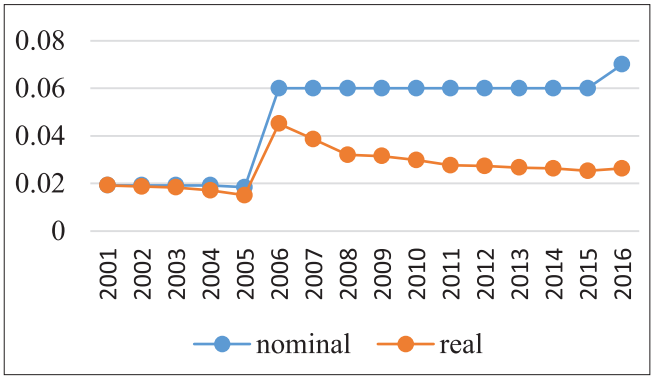
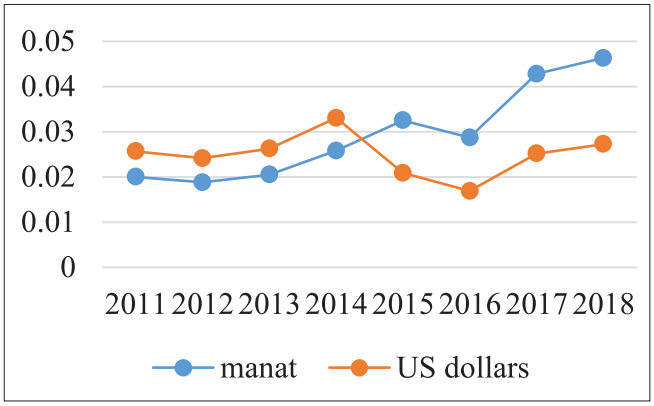


Figure 3: Average costs of per 1 kWh of electricity generated by ATPS



compensated by the state, since revenues are formed on the basis of prices established by the Tariff Council.

The costs for ATPS personnel has not changed significantly over the past 8 years. The absence of significant differences in wages indicates that there is no significant improvement in the social

Table 3: Dynamics of nominal and real marginal revenue at the azerbaijan thermal power station (thousand manat/MWh)

Years	Average nominal income from the sale of energy	Average real income from the sale of energy	Total nominal income-(thousand manats)	Total real income (thousand manats)	Total average nominal income	Total average real income	Marginal nominal income	Marginal real income
2011	0.019	0.019	133074.0	133074.0	0.0212	0.021	-	-
2012	0.018	0.017	145534.0	139267.0	0.0179	0.017	0.0068	0.0065
2013	0.018	0.018	142441.0	141591.5	0.0187	0.019	0.0063	0.0062
2014	0.025	0.027	193976.0	213160.4	0.0252	0.028	1.0217	1.1228
2015	0.032	0.050	240080.0	373374.8	0.0324	0.050	-0.1642	-0.2553
2016	0.027	0.028	186854.0	192831.8	0.0276	0.029	0.0831	0.0858
2017	0.042	0.026	345100.0	210042.6	0.0423	0.026	0.1133	0.0689
2018	0.037	0.022	296791.0	182304.1	0.0397	0.024	0.0697	0.0428
Average	0.027	0.026	210481.3	198205.8	0.028	0.027	0.162	0.154

Calculated by authors by using dates from Azerenerji (2018)

Table 4: Dynamics of nominal and real costs for ATPC

Years	Volume of production (thousand kWh)	Share of production in potential production (%)	Total nominal costs (thousand man.)	Total real costs (Base year: 2011) (thousand man.)	Average nominal costs (manat /kWh)	Average real costs (man/kWh), (base year: 2011)	Marginal nominal costs (dman/dKW hour)	Marginal real costs (d man/d kW), (base year: 2011)
2011	6289234	29.9	125849	125849	0.020	0.0200	-	-
2012	8126446	38.7	152964	151300	0.019	0.0188	0.0148	0.0069
2013	7633202	36.3	156317	151031	0.020	0.0193	0.0068	0.0065
2014	7683640	36.6	198029	188599	0.026	0.0248	0.8270	1.0728
2015	7402814	35.3	240948	220648	0.033	0.0302	0.1528	-0.1793
2016	6762489	32.2	193804	157949	0.029	0.0236	0.0736	0.1020
2017	8159728	38.9	348978	251788	0.043	0.0310	0.1111	0.1570
2018	7466651	35.6	345809	243871	0.046	0.0324	0.0046	0.0988
average	7440526	35.4	220337.3	186379	0.0295	0.0250	0.170091	0.1807

Calculated by authors according to (TCRA, 2018; SSCRA, 2018; Azerenerji, 2018)

Figure 4: The modeling for selling prices and production volume of "Azerenerji" in conditions of state natural monopoly and competitive market

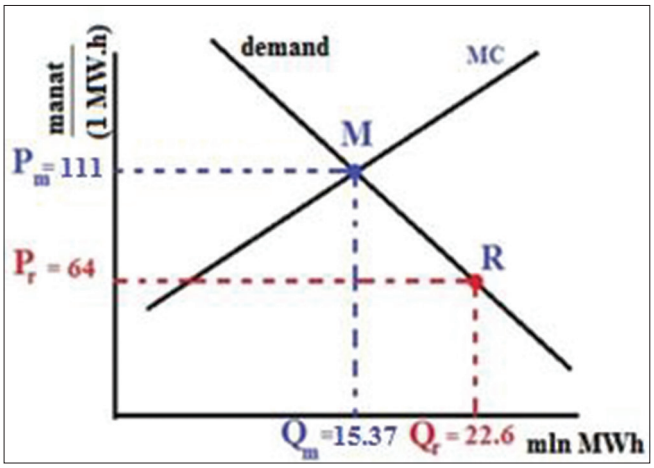
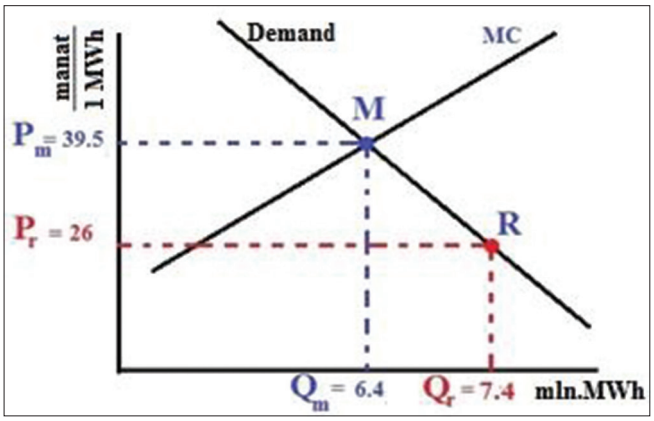


Figure 5: The modeling for comparison of wholesale selling prices and production volumes at ATPS at the competitive market and state natural monopoly



status of workers of ATPS. The costs of raw materials, maintenance and repair, depreciation of fixed assets and other operating costs varied in volume over the years. Such changes do not have a serious relationship with production volumes. The assessment shows that the Pearson correlation coefficient between the volume of production (thousand kWh) and the total nominal costs does not exceed r = 0.41.

Revenues from ATPS sales are significantly less than its total costs and, therefore, ATPS is a loss-making enterprise. Estimates over the past 8 years show that sales revenue exceeded ATPS operating costs only in 2018. In 2011-2017, operating costs were higher than sales revenue. Subject to other costs, ATPS total costs for the period 2011-2018 exceeded total revenue. It should be noted that the average income at the station changes dramatically over the years (Table 3). So, in 2011, 2012 and 2013, revenue from the sale of 1 kWh determined to 1.9; 1.8 and 1.8 qepiks[2], respectively, and in 2018 it settled to 3.6 qepiks. The increase in sales revenue in 2018 is likely due to differentiation and, in fact, an increase in electricity prices. Compared to 2011, the volume of production in 2018 increased 1.19 times, and costs increased 2.7 times. Sales revenue for the same period increased 2.2 times. The cost of fuel for the production of 1 kWh at ATPS in 2011 was significantly lower than in 2018. So, in 2011 fuel consumption decreased to 1.3 qepiks/1 kWh, and in 2018 - 2.9 qepiks. It should be noted that prices for oil and natural gas in the domestic market in 2018 were slightly higher in manats than in 2011. The reason for the significant difference in fuel consumption in ATPS for 2011-2018 is, most likely, the technical characteristics of the equipment.

4.4. General and Average Cost Function for Thermal Power Plants Azerbaijan

If we take the maximum amount of electricity produced by ATPS with a capacity of 2400 MW equal to 21 million MWh, then we will see a fluctuation of the production share in potential production between 30% and 40% in the period 2011-2018. Over the past 8-9 years, ATPS capacity has been used steadily in this interval to ensure Azerbaijan's electricity balance. This allows to generate about 6-8 million MWh of electricity. Assuming that most of the costs are fuel costs, while other costs have not changed much, the ATPS total cost function can be expressed by the formula (Geoffrey and Tomas, 2003) $TC = a * Q^2 + b * Q + c$, and the average cost function as $AC = \frac{TC}{Q}$. When calculating costs, it would be more accurate to take costs in real prices based on a base year (e.g., relative to 2011) (Figure 2), or costs calculated in US dollars. Empirical calculations performed using the least square method show that the ATPS total cost function for the period 2011-2018 can be expressed approximately in the form (4), (5) and (6), respectively, in nominal prices, real prices and US dollars:

$$TC = 2.10^{-5} * Q^2 - 258.67 * Q + 9 * 10^8 \quad (4)$$

$$TC = 4.10^{-6} * Q^2 - 11.736 * Q + 7 * 10^7 \quad (5)$$

$$TC = 10^{-5} * Q^2 - 100 * Q + 4 * 10^8 \quad (6)$$

It should be noted that the figures for 2012 are not included in the calculations. In 2012, compared with 2011, with an increase in production by almost 2 million MW, the increase in costs amounted to only 25 million manat, in subsequent years, on the contrary, with a decrease in production, costs increased. This is most likely due to the reconstruction and acquisition of fixed assets in 2012. Therefore, for simplicity, this year's figure was not taken into account. ATPS's actual total costs for the period 2011-2018 differ from the estimated total costs in empirical models (4) and (6).

We will use only model (5), since this model, calculated on the basis of real prices, gives results close to actual costs. Using this model, the short-term function of marginal costs (MC) for ATPS can be expressed as:

$$MC = \frac{dTC}{dQ} = 8.10^{-6} \quad Q - 11.736 \quad (7)$$

Where, Q is the volume of generated electric energy (MWh), MC is calculated in manats. Calculations using formula (7) show that

2 1 qepiks = 0.01 manat= 0.0128 US dollar in 2011-2014 and 1 qepiks = 0.01 manat=0.00588 US dollar in 2016-2018.

ATPS's short-term marginal costs for per 1 MWh of energy in 2011-2018 changed from 38.5 to 53.5 manat. Over this period, the average short-term (i.e. annual) marginal costs amounted to 47.8 manat. Based on real prices, marginal costs calculated in the long term, i.e., 2011-2018, amount to 100 manat for each MWh. This is close to the average marginal cost at that time.

We will use two points to build the marginal cost function for the long-term period, covering 2011-2018. The first point is the point of marginal costs for the long-term period, covering 2011 and 2018, i.e., the point (7.5 million MWh; 100 manat), the second point is the point of marginal costs of medium production and average costs in relation to 2011, i.e., the point (74.4 million MWh; 52.58 manat). The function of long-term marginal costs built on the basis of these empirical points is expressed as follows:

$$MC = 1.8 \times 10^{-3} \times Q - 13340 \quad (8)$$

The ATPS long-term marginal cost function (5) is very different from the short-term marginal cost function (8). The main reasons for this are related to sharp fluctuations of factors in the long run on which the components of operating costs depend.

It should be noted that ATPS's nominal marginal costs for 2011-2018 also differ sharply from each other. Since, in some years, these costs are very high. For example, marginal costs increased sharply as a result of a slight increase in production in 2014 and 2017. In 2014, marginal costs increased to 827 manat/1 MWh. Accordingly, production volumes in 2013 and 2014 were equal to 7.6 and 7.7 million MWh, and although the fuel consumption required for production did not differ significantly over the years (329-336 kg/MW) differences between the annual cost of fuel used were reflected in marginal costs. ATPS's average costs (Figure 3) for 2011-2018 exceeded average revenue (Table 4).

Average marginal revenue is also lower than average marginal cost. Marginal revenue depends not only on production, but also on prices. The marginal revenue function for ATPS can be expressed as,

$$MR = \frac{dTR}{dQ} = \frac{d(P \quad Q)}{dQ} = Q \quad \frac{dP}{dQ} + P \quad (9)$$

as the supply function in a competitive market also depends on prices. Here, *P(Q)* is the demand function.

The energy demand function for HHs can be expressed as $= \frac{\propto}{Q^{\beta}}$,

and then α and β can be determined on the basis of total HH electricity consumption and real prices over the past 17 years. Since ATPS is an integral part of the absolute monopoly electricity supplier in Azerbaijan, short-term elasticity can be found based on the equation

$$e = \frac{\frac{dQ}{Q}}{\frac{dP}{P}} \quad (10)$$

If we accept 2017 y. (when real prices were minimum, i.e., 23.3 manat/MWh) and 2006 y. (when prices were maximum, i.e., 45 manat/MWh), as limit years for the variable (P) the price functions, then 23.5 GWh and 20.8 GWh respectively, should be taken as limits for variable of output to solve (equation 10). If we solve differential equation (10) in the form indicated above, then we can get e = −0.2. Over the past 18 years, the elasticity of HHs' electricity demand at prices has been around e = −0.2. Using this value of elasticity, we can find the HHs electricity demand function by solving differential equation (11).

$$\int_{2.1*10^{7}}^{Q} \frac{dx}{x} = -0.2 * \int_{23.3}^{P} \frac{dy}{y} \quad (11)$$

The electricity demand function can be expressed as

$$P = \frac{9.55*10^{37}}{Q^{5}} \quad (12)$$

by solving differential equation (11). Here P is expressed in manat, and Q is measured in MWh.

In the long run, we can find the elasticity by the formula $\frac{\Delta Q / \bar{Q}}{\Delta P / \bar{P}}$.

Calculations show that during 2011-2017, the elasticity of electricity demand at prices is e = −0.8. The coefficient of elasticity for a long period is also too small. Despite the fact that the coefficient of elasticity is a rather inert indicator, its change takes place in connection with a change in the structure of expenditures of the population. By the changing of income, the share of electricity expenditure is changing. In the long run, HHs can reduce share of the electricity expenditure or replace it with other types of energy source, e.g., gas.

The nominal prices for electricity sales in Azerbaijan for the period from 2001 to 2017 is changed 3 times and increased from 0.0184 to 0.07 manat. However, the real price was also the highest in 2016. In this case, the demand elasticity for electricity produced by ATPS will be equal to $e \quad \frac{Q_{AOES}}{Q_{total}} = -0.8 * 0.315 = -0.05$. Here, $\frac{Q_{AOES}}{Q_{total}}$ – this is ATPS's share in the volume of electricity produced in Azerbaijan. It seems that the demand elasticity for electricity produced by ATPS is much less in the long run. The demand function can be found by solving the differential equation

$$\int_{6.3*10^{6}}^{Q} \frac{dx}{x} = -0.05 * \int_{60}^{P} \frac{dy}{y} \quad (13)$$

using the ATPS elasticity value. Thus, the demand function for ATPS can be expressed as

$$P = \frac{5.8*10^{137}}{Q^{20}} \quad (14)$$

The average cost of electricity produced by "Azerenerji" OJSC has constantly increased in manat in the period of 2011-2018

(excluding 2016). The average cost in dollars also tends to increase before the devaluation of Azerbaijan currency in 2015. Although there was a decline after 2 years of devaluation, then recovery took place. In both cases, there is no pattern in the dependence of average costs on the volume of production. Although the bulk of "Azerenerji" OJSC costs is largely dependent on fuel consumption and cost, average costs are independent of production. 329.31 kg of fuel was spent on the production of 1 MWh of electricity at this station in 2012, while in 2009 fuel consumption increased to 358.26 kg for 1 MWh. Probably, this was due to the upgrade of technical equipment. Using the real marginal cost functions (4) and (6) and the demand function (13) for "Azerenerji" OJSC, we can determine the possible equilibrium values in which a competitive market can function. In this case

$$\begin{cases} P_m = 8.10^{-6} * Q_m - 11.736 \\ P_m = \dfrac{9.55*10^{37}}{Q_m^{\,5}} \end{cases} \quad (15)$$

Solving system equation (15), we can obtain expected values for P_m = 111 manat and Q_m = 15.37 million MWh. Where P_m -is expected market price and Q_m -is expected quantity demanded in market equilbirium. In other words, in the competitive market, by increasing the cost of selling electricity to the HHs will be increased price of electricity in compare with current regulated prices and will be reduced amount of consumption.

Similar calculations can be made for ATPS. In this case, P_m is the wholesale selling price of the energy produced by ATPS to Azerenerji in the competitive market, and Q_m is the ATPS production volume in the competitive market. In this case, we need to solve the system equation (16).

$$\begin{cases} P_m = 8.10^{-6} * Q_m - 11.736 \\ P_m = \dfrac{5.8*10^{137}}{Q_m^{\,20}} \end{cases} \quad (16)$$

By solving the system equation (16), one can obtain expected values for P_m = 39.5 manat and Q_m = 6.4 million MWh. In other words, in a competitive market, the expected equilibrium values for the electricity generated by ATPS will be slightly higher relative to current regulated values, and expected production volume will be slightly lower.

An approximate scheme of possible changes in prices under the conditions of a state natural monopoly and a competitive market environment for "Azerenerji" and ATPS provides the basis for asserting that currently regulated prices are much lower than free market prices. So large production volumes lead to power plants' financial losses. As usual additional funds are allocated from the state budget to improve social conditions and fully satisfy the electricity demand in the country. At present, raising prices to the level of market equilibrium can create additional financial difficulties for the general population. At present, a significant part of HH expenses (about 6%) is accounted for electricity consumption. Due to the lack of elasticity of electricity demand, rising prices to the level of market equilibrium can seriously change this percentage. In this case, it may be necessary to compensate additional expenditure of the HHs with small incomes.

It is possible to calculate changes in consumer surplus and producer surplus as the trapezoid area (P_mMRP_r) for "Azerenerji" and ATPS in the Figures 4 and 5, respectively. For "Azerenerji" in the transition from regulated prices (*Pr*) to market (*Pm*), consumer surplus decreases in volume as

$$(P_m - P_r) * (Q_r + Q_m)/2 = (111-64) * (22.6 + 15.37)*10^6/2 = 892,3*10^9 \text{ (manat)} \quad (17)$$

And for ATPS in the transition process from regulated prices (*Pr*) to market (*Pm*), consumer surplus decreases in volume as

$$(P_m - P_r) * (Q_r + Q_m)/2 = (39.5-26) * (6.4 + 7.4) * 10^6/2 = 93.15 * 10^6 \text{ (manat)} \quad (18)$$

Naturally, the bulk of consumption is not related to the HHs and has mainly commercial character. Therefore, there is a need to compensate the losses of low-income HHs in case of the transition process from state natural monopoly to the competitive market to reduce the social burden.

5. CONCLUSIONS

So, by using the demand function and marginal cost function for electricity, we have established model to calculate the price changing in transition from natural state monopoly to the competitive market and to calculate consumer surplus changing for the countries where electricity price is regulated by state. In case of Azerbaijan where electricity prices are regulated by state we have proved that current electricity price is much lower than if it would be established in the free market. Therefore, electricity power plants are absolute monopolists and are state enterprises, they incur losses that are covered by the state budget to protect consumers. However, at the same time, demand increases, and sometimes leads to unjustified consumption and waste. In order to protect the interests of consumers, there is no need to keep the price of electricity below the market and it is necessary to ensure a free electricity market in the country.

Calculations by offered model show that in the transition process from monopoly pricing to market pricing, the price will be necessarily increased and the consumer surplus will be decreased. Therefore, it is necessary to carry out the privatization of the electricity sector and at the same time to carry out a policy to compensate the losses of low-income HHs from rising electricity prices in order to acquire the minimum required amount of electricity for these HHs. The transition process from an absolute state monopoly in the electricity sector to the market will increase the quality of electricity supply, the volume of investments in this sector, reduce excessive consumption, reduce the burden of the state budget aimed at covering the losses of producers.

REFERENCES

Azerenerji. (2018), Reports of Azerenerji JSC. Available from: http://www.azerenerji.gov.az/index/page/11/?lang=en. [Last accessed on

2019 Apr 15].
Brue, S.L., Grant, R.R. (2007), The History of Economic Thought. Mason, OH: Thomson Southwestern.
Cartea, A., Figueroa, M.G. (2005), Pricing in electricity markets: A mean reverting jump diffusion model with seasonality. Applied Mathematical Finance, 12(4), 313-335.
Geoffrey, R., Tomas, G. (2003), Electricity Economics: Regulation and Deregulation. Hoboken: John Wiley and Sons Publication.
Greer, M. (2011), Electricity cost modeling calculations electricity cost modeling calculations. Amsterdam, Boston: Elsevier. p313.
Gulaliyev, M., Aga, A., Azizov, A., Kazimov, F., Mir-Babayev, R. (2018), Assessing the degree of inequality in the distribution of national income and its macroeconomic consequences in Azerbaijan. Espacious, 7(17), 85-108.
Guthrie, G., Videbeck, S. (2002), High Frequency Electricity Spot Price Dynamics: An Intra-Day Markets Approach. Available from: <https://www.ssrn.com/abstract=367760>. Last accessed on 2019 May 11].
Holmberg, P., Newbery, D.M. (2010), The supply function equilibrium and its policy implications for wholesale electricity auctions. Utilities Policy, 18, 209-222.
Juan, F.E., Alejandro, J. (2010), Monopolistic competition in electricity networks with resistance losses. Economic Theory, 44, 101-121.
Julian, L.S., Edward, M.R. (1983), The theory of price-changing and monopoly power. Journal of Post Keynesian Economics, 6(2), 198-213.
Madhu, K., Narasimha, D.R. (2009), Supply and demand of electricity in the developing world. The Annual Review of Resource Economics, 1, 567-596.
Misiorek, A., Trueck, S., Weron, R. (2006), Point and interval forecasting of spot electricity prices: Linear vs. Non-linear time series models. Studies in Nonlinear Dynamics and Econometrics, 10(3), 1-36.
Naceur, K., Muhammad, S., Hrushikesh, M., Nanthakumar, L. (2018), Estimation of electricity demand function for Algeria: Revisit of time series analysis. Renewable and Sustainable Energy Reviews, 82(3), 4221-4234.
Popova, J. (2004), Spatial Pattern in Modeling Electricity Prices: Evidence from the PJM Market. West Virginia University Working Paper.
Rafał, W. (2014), Electricity price forecasting: A review of the state-of-the-art with a look into the future. International Journal of Forecasting, 30(4), 1030-1081.
Serletis, A., Shahmoradi, A., (2006), Measuring and testing natural gas and electricity markets volatility: Evidence from Alberta's deregulated markets. Studies in Nonlinear Dynamics and Econometrics, 10(3), 1-20.
Seung-Hoon, Y., Joo, S.L., Seung-Jun, K. (2007), Estimation of residential electricity demand function in Seoul by correction for sample selection bias. Energy Policy, 35(11), 5702-5707.
Shi, G., Zheng, X., Song, F. (2012), Estimating elasticity for residential electricity demand in China. The Scientific World Journal, 2012, 395629.
SRM. (2016), Strategic Road Map on Development of Utilities (Electricity and Thermal Energy, Water and Gas) in the Republic of Azerbaijan. Available from: https://www.president.az/articles/22368. [Last accessed on 2019 Apr 25].
SSCRA. (2018), State Statistical Committee of Republic of Azerbaijan. Available from: https://www.stat.gov.az/menu/4/e-reports. [Last accessed on 2019 May 10].
TCRA. (2018), Tariff (Price) Council of the Azerbaijan Republic. Available from: http://www.tariffcouncil.gov.az/?/en/resolution/archive. [Last accessed on 2019 May 27].