ANTICIPATING THE IMPACT OF THE PLANNED INCREASE IN ELECTICITY TARIFFS ON THE UKRAINIAN ECONOMY

by

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Abstract

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This thesis is devoted to analysing electricity market in Ukraine, segmented according to two types of consumers (industrial consumers and residential users). Electricity is supplied by energy distributing companies ('oblenergos') at tariffs regulated by the National Electricity Regulating Committee (NERC). The sector suffers from insufficiency of the tariff revenues to cover *all* the costs including the industry's needs to invest in capital replacement. NERC is currently considering increases in electricity tariffs. My thesis attempts to answer the following question: How will the increase in electricity tariffs, currently planned by NERC, affect the players of this market? The conventional cost-benefit analysis of welfare effects of tariffs increase is used as the basic method. The primary focus is on *estimating price elasticities of electricity demand* based on data from NERC and Ukrainian State Committee of Statistics for the period from 1996 to 2000 on monthly basis. The most appropriate estimation procedures are chosen from several alternative techniques presented in the literature. To my knowledge, there are no estimations of price elasticity of electricity demand in Ukraine in the literature; thus, my thesis is a first attempt in this respect. The thesis question is extremely topical due to electricity being a crucial input in most industries and due to the large share of energy in the Ukrainian economy. Moreover, my research is particularly significant in the wake of the planned tariff increase, and the results of this study are expected to have implications for further tariff policy being considered by NERC.

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The highest gratitude is addressed to my family for their moral support and love given to me.

GLOSSARY

Cross-Subsidization. Implicit subsidizing of one group of consumers by another one as a result of setting different tariffs for them by governmental regulation.

Efficiency of Production. The state of industrial organization where the most cost-efficient firms work in the industry.

Electricity Tariff. A unit price (UAH per kWh) of electricity delivered.

Oblenergo. Ukrainian term for a local electricity distributing company.

Residential Holdings. Households as electricity consumers.

Social losses. The term is used to refer to difference of the value of total surplus in electricity market from the one which would be under marginal cost pricing.

White Goods. Electricity-using appliance possessed by residential holdings.

Welfare Analysis. Is used in this thesis to refer to the analysis of changes in consumer and producer surpluses in aggregate.

LIST OF ABBREVIATIONS

CPI – Consumer Price Index

FR – Freezers and Refrigerators (in regressions)

FSU – Former Soviet Union

GSS – Gain in Supplier's Surplus

HT – Household Electricity Tariffs (in regressions)

IRIP – Index of Real Industrial Production (in regressions)

IT – Industrial Electricity Tariffs (in regressions)

kWh – Kilowatt*hour (Measurement unit of the physical amount of electricity consumed)

LCS – Loss of Consumer Surplus

LCS_I – Loss of Consumer Surplus in Industrial Sector

LCS_R – Loss of Consumer Surplus in Residential Sector

LSS – Loss of Supplier's Surplus

LSS_I – Loss of Supplier's Surplus in Industrial Sector

LSS_R – Loss of Supplier's Surplus in Residential Sector

NG – Net Gain

NERC – National Electricity Regulating Committee

PPI – Producer Price Index

PS – Producer Surplus

RHT – Household Electricity Tariffs (in regressions)

RIT – Real Industrial Electricity Tariffs (in regressions)

TV – TV-sets

UAH – Ukrainian Hryvnya (National currency unit of Ukraine)

UAH kop – Kopeks of Ukrainian Hryvnya

VC – Vacuum Cleaners (in regressions)

WEM – Wholesale Electricity Market

Chapter 1

INTRODUCTION

In the former USSR, electricity was hardly a tradable good. Rather, for ideological reasons, it was treated as a public good, as 'an inalienable human right'[1], and provided by the state at heavily subsidized prices. Consequently, Ukraine started the transition to the market economy with electricity tariffs that were far lower than the cost of its production and distribution.

In this thesis, I analyse Ukrainian electricity market, where the typical agents are: enterprises and residential holdings – buyers, – on the one hand, and energy distributing companies ('oblenergo') – sellers, – on the other. Some of the 'oblenergos' are privatized, others are owned by the state. The latter considers oblenergos as natural monopolies and, as such, subject to regulation by the National Electricity Regulating Commission (NERC).

NERC's primary concern is to set proper tariffs on electricity charged by oblenergos. The regulatory body has currently announced its intention to substantially increase electricity tariffs.[2]

In my thesis, I attempt to answer the following question: How will the increase in electricity tariffs, currently planned by NERC, affect the players of this market?

The motivation behind raising this question includes several reasons. First, this question is extremely topical due to electricity being a crucial input in most industries and to large share of energy sector in Ukrainian economy. Second, quantitative estimates of price elasticities of electricity demand in Ukraine (used in attempt to answer the thesis question) have not been presented in the literature so

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[1] See: Dodonov et. al. (2001)

[2] Infobank. (2001). Newsletter. Nov 21-1.

far. Moreover, my research is particularly significant in the wake of the planned tariff increase, and the results of this study are expected to have implications for further tariff policy being considered by NERC.

Despite several tariff increases, the situation remains problematic. However, even brief international comparisons, as well as basic economic theory, suggest that, if Ukraine is to transform into a successful *market economy*, the electricity tariffs will have to increase to cover the costs in the long run.

The government's plans to increase the electricity tariffs have been reportedly motivated by the above considerations.[1] The final decisions are likely to depend on a large number of factors, some of which lie beyond the scope of standard welfare analysis. Under the maintained assumption of social welfare maximization as the primary goal of all regulations in the industry, electricity tariffs need not reach their long-run break-even level (expected above) at once. Several small increases may (and intuitively seem to) be socially more desirable. The *costs* and *benefits* of any proposed tariff increase should be weighed. They are in principle known to the regulatory body, but mostly on the *qualitative* level. For improving efficiency, it needs *quantitative* estimates of the consequences of an increase in electricity tariffs, estimates that approximate the reality to as large an extent as possible given the costs involved in obtaining all the relevant data.

The conventional cost-benefit analysis suggests alternative methods of evaluating the welfare changes. More simple ones are estimating *equivalent variation* and *compensating variation* for consumers from the tariff increase. The former may underestimate, and the latter may overestimate consumers' welfare loss. Dodonov et. al. (2001) applied both methods to estimate the households' welfare losses from raising electricity tariffs to the cost-covering level.

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[1] See, for a good discussion, Dodonov et. al. (2001).

However, anticipating welfare consequences of *several* tariff increases for residential consumers, in conjunction with increases in *industrial* tariffs, requires estimating price *elasticities* of electricity demand. Estimation of elasticities is crucial for welfare analysis; in particular, for estimating changes in *surpluses* of *all* market agents.

Hence, my thesis primarily focuses on estimating price elasticities of electricity demand based on data from Ukrainian State Committee of Statistics, NERC, Ukrainian State Ministry of Finance, and NBU for the period from 1996 to 2000 on monthly basis.

In principle, the amount of electricity demanded by residential holdings depends on several factors such as: electricity tariffs, stock of electricity using appliance possessed by households, households' incomes, and prices of other goods. The industrial electricity demand depends on the industrial electricity tariffs and the real industrial production, since it is a *derived* demand.

For estimating the price elasticity of residential holdings' demand, a Ukrainian-context justification of model by Hsiao and Mountain (1985) is used. Also, a point is derived from Berndt's discussion of the two major principal approaches to 'white goods' stock inclusion: the explicit and implicit one. The former is preferable for the short-run analysis due to its capability to separate observed changes in electricity demand resulting from shifts in white goods' utilization rates caused by tariff changes from those explained by changes of equipment stocks. The preference in my thesis is, thus, given to this type of specification. For estimating the price elasticity of industrial electricity demand, a Ukrainian-context justification of Bjørner's modelling methodology is used.

The thesis is structured into several parts devoted to the underlying theoretical concepts of welfare analysis, specific characteristics of Ukrainian electricity market and available data on it, principal technique and the actual procedure of estimating elasticities of electricity demand, and using the resulting estimates in welfare calculations with implications for subsequent electricity-tariff policy of Ukrainian government.

Chapter 2

LITERATURE REVIEW

The major literature agenda for my thesis is described below and the essence of its relevance to this research is discussed. The information I need to gather in the literature first of all is methods of case studies on electricity demand conducted in different countries.

Though I evaluate the influence of the new tariff policy on Ukrainian economy, here, I basically concentrate on studying the techniques of estimating the elasticity of electricity demand crucially needed in such a research, since it presents little usefulness to re-formulate conventional comparative statics, described in most microeconomic textbooks.

The serious research in modelling demand for electricity was pioneered by Houthakker (1951), who obtained valuable estimates of electricity price and income elasticities using GLS rather than OLS. He also was the first to state that using marginal prices is superior to using ex post average prices.

The chapter on "The Demand for Electricity: Structural and Time Series Approaches" in: Berndt (1996) constitutes the basic general methodological source for my thesis. Berndt provides an overview of existing ways to modelling electricity demand involving two principal approaches: the one including equipment stocks explicitly and that including it implicitly. The strong and weak sides of each approach are discussed, including the degree of appropriateness of the methods for short-run and long-run analysis.

Indeed, in the former, explicit inclusion of the equipment stock is enough, since consumers cannot change it to adjust for any changes in electricity price. Thus, Fisher & Kaysen (1962) correctly formulate the principal first-difference equation for estimating electricity demand as regressing ΔLog[el. consumption] on ΔLog[el. price] and ΔLog[real per capita income], the intercept of the estimated equation representing the *constant* rate of growth in stock of households' electricity consuming equipment. The estimated short-run price and income elasticities lead authors to meaningful conclusions; however, their *long*-run saturation models are regarded by several researchers as weak, Berndt (1996) reports (p. 315).

Berndt shows that adequate *long-run* estimates must be obtained from models *indirectly* including equipment stock. In those models, in the simplest form, a (log of) long-run desired electricity consumption is regressed on logs of all factors that influence it. While this regressand is a latent variable, hypotheses about the type of adjustment become crucial. Those are suggested by the corresponding theories, and each implies a specific type of estimation technique, as well as results in a model with certain explanatory and predictive capabilities peculiar to it. The basic alternative types of adjustment assumed are: partial adjustment (with the coefficient of it to be estimated) and nonstatic expectations. Within the latter, adaptive expectations hypothesis can be chosen, which generally requires Koyck transformation and involves a maximum likelihood or instrumental variable procedure. Alternatively, rational expectations can be assumed, reducing the task to MA(1) modelling according to Box-Jenkins estimation technique.

The weak side of 'implicit-stock' type of models is their limited capability to separate observed changes in electricity demand on the two components resulting from shifts in equipment stocks and from that in utilization rates.

Because of this weakness of the 'implicit-stock' models, and since I focus on the short run analysis, I adapt 'explicit-stock' type models for my study.

Berndt (1996) also addressed three typical problems in choosing model setup: the choice of model's functional form, consequences of omitting the intramarginal price, and the simultaneity of electricity quantity and price, the latter having the most ambiguous implications. He shows that omitting the intramarginal price as a regressor has only a minor impact on estimation results.

A valuable discussion of several bright empirical works is also presented by Berndt (1996), serving as a good overview of examples for similar studies in the field.

Another core article in the area is by Bjørner et. al. (1998). They study the case of Danish industrial companies. Their research is devoted to the consumption of energy in total; however, it includes separate accomplished models of *electricity* consumption, which are basic in the general exposition. The principal model of demand for electricity results from regressing (in logs form) the quantity demanded on real value added and real price for electricity. The coefficient at the latter is the price elasticity – the primary concern of my thesis. This basic model is then extended to incorporate micropanel data structure and exogenous technological change. Estimation and testing of the models shows that their parameter estimates are very sensitive to the choice between fixed-effects and random-effects specification (e.g. DRS are concluded from the former, while CRS – in the latter). Although the random-effects models excel in efficiency, fixed-effects specification is preferred due to its sole ability to capture unique characteristics of companies. The most important advantage of the described models is that they yield *robust* (with respect to the chosen specification of electricity and total energy demand) estimates of value added and price elasticities.

The above procedures and conclusions are important to study as a benchmark for my research, since they constitute a good point of departure from a pattern for the format of my methodological viewpoint.

Among residential-level studies, Hsiao and Mountain (1985) is of special interest as a point of departure from basic residential electricity demand model specification. They suggest a model for estimating the income elasticity of households' electricity demand, which includes the following factors determining household demand for electricity: electricity tariffs, price of composite 'other goods', incomes, and possession of electricity-using equipment. Such a specification includes variables, Ukrainian data for which are obtainable, and is appropriate for use in electricity demand modelling in my thesis.

Rhys (1984) provides an overview of existing techniques of estimating electricity demand and traces their relative merits. Rhys's overview presents a methodological framework, which is useful for my analysis. Besides, it contains concisely formulated valuable general principles of approaching the issue. In particular, Rhys defines the purpose of electricity demand modelling as being "to limit the extent of uncertainty and provide the best basis for planning" (p. 23). He also defines the reasonable limitations of timing and precision in anticipations – respectively the medium run and specification of estimates as "central «predictions», upper and lower bounds of a range, scenarios, or targets to be achieved" (p. 24).

Giving respect to generally dominating uncertainty about electricity demand elasticity issue, Rhys classifies the techniques of demand forecasting into 3 groups: statistical interpretation and projection of past trends, econometric approach, and detailed case studies. In my thesis, I use the first two.

The literature described above constitutes principally integral methodological setup for my thesis.

At the same time, the room for my research in the topic obviously exists, since, to my knowledge, no paper on estimation price elasticities of Ukrainian electricity demand is found in the available literature. The welfare consequences of electricity tariffs increase on industries in Ukraine have not been studied either. Moreover, most of the sources I acquainted with are devoted to studying electricity demands either only in industrial or only in residential sector, whereas my thesis tackles both.

So, my major contribution in the thesis lies in applying general theory and econometric methods to the specific conditions of Ukrainian economy in transition.

Chapter 3

THEORY AND METHODOLOGY

To evaluate the impact of the electricity tariffs increase on Ukrainian economy, I use the conventional methodology of cost-benefit analysis. To evaluate the welfare consequences (for buyers and sellers) of any change in market equilibrium, one needs to estimate changes in consumer and producer surpluses. The deadweight losses are used to evaluate the equilibrium from the point of view of efficiency; hence, change in deadweight losses can be used for assessing the impact of the change in market equilibrium on the society as a whole.

In the case of tariff increase studied in my thesis, the essence of the procedure lies in estimating the welfare consequences of this increase on buyers and sellers in the electricity market.

The welfare consequences are measured by changes in consumer and producer surpluses, and the resulting social outcome is evaluated by the change in social losses (as reducing them is socially desirable).

The framework of the analysis is presented in the following graph:

Figure 1. Welfare Effects from Increase in Tariff Ceiling

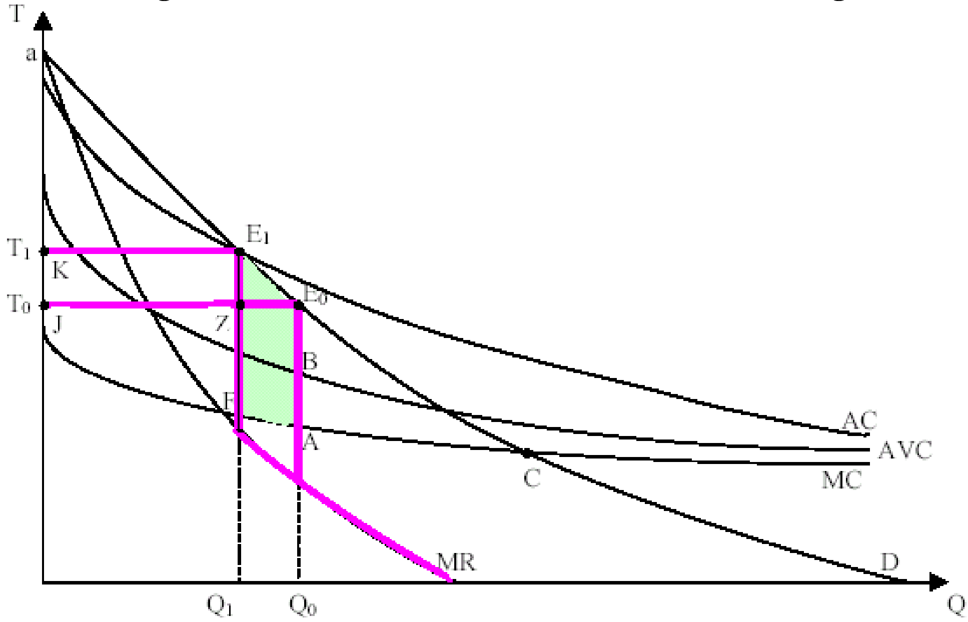

Figure 1 describes electricity market (each of its segments – industrial and residential –can be illustrated in the same graph) with electricity demand curve D (downward-sloping, since electricity is an ordinary good) and the associated marginal revenue curve MR (for electricity seller) in the absence of regulation (the actual shape of MR, affected by regulations, is discussed below). The supply-side is described with marginal cost (MC), average variable cost (AVC), and long-run average total cost (AC) curves. Since the case of a natural monopoly is under consideration, the cost curves in the Figure are all decreasing (which means increasing returns to scale). In principle, with Q infinitely increasing, the cost curves would not monotonically decrease, since increases in the generating capacities (fixed costs) would be periodically required. However, in the reasonable output range which I consider, changes in production capacity does not occur; therefore, the cost curves can be depicted in the above way.

Suppose, initially, a tariff ceiling is imposed at the level T_0, which results in equilibrium at point E_0, with Q_0 of electricity trade. Since, at any level of production below Q_0, suppliers earn only T_0 on each additional unit sold, the marginal revenue MR curve is horizontal on the interval from 0 to Q_0.

After Q_0, reduction in tariff by oblenergo increases the electricity consumption by a positive amount; thus, MR is downward-sloping after that point.

The resulting MR-curve is, therefore, kinked at the point E_0.

In this equilibrium, the consumer surplus is equal to the area T_0aE_0[1]; the producer surplus is equal to the area JT_0E_0A[2]; and the social losses[3] are equal to the area AE_0C, the point C representing the (imaginary) competitive solution.

The social losses AE_0C constitute a part of conventional social losses from a monopoly remaining after the imposition of the tariff ceiling (aimed at moving the equilibrium closer to the competitive one).

The described equilibrium is socially preferable to an unregulated monopoly case, but there is a problem: due to factors described in the discussion of the specifics of Ukrainian electricity market, electricity industry (seller in my model) covers average variable costs AVC, but fails to invest in capital replacement, i.e. current electricity tariffs fail to cover the average total costs, which are shown in the graph by the line AC crossing the demand curve above the current electricity

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1 For a direct reference to assessment of a change in consumer surplus, see Nicholson (1998), p.154: Figure 5.9.

2 For a direct reference, see Nicholson (1998), p.382: shaded area in Figure 13.4 (the integral of distance between price and MC-curve) represents short-run producer surplus.

3 I use the term 'social losses' here instead of 'deadweight losses' (which are discussed in standard analysis) in order to clearly trace the scope of my analysis which does not include considerations about availability of capturing those losses by some of the market players in the ideal situation (a non-obvious issue in case of the natural monopoly). The scope of my analysis limits to comparative statics, and the term 'social losses' is used to refer to differences in total surplus in electricity market from that which would be under marginal cost pricing.

price (tariff). Without such investment in equipment, electricity industry is likely to incur high maintenance cost on its obsolete capital.

Therefore, electricity industry's lobby argue for the government to increase the tariff ceiling, and the latter is currently planning to do so.

The equilibrium will thus move to E_1, thus improving the conditions of suppliers. Their surplus will be equal to the area T_1E_1FJ, i.e. it will increase by the area $[T_0T_1E_1Z - ZE_0AF]$. The part $T_0T_1E_1Z$ will be transferred from consumer surplus, and ZE_0AF will add to social losses. Consumer surplus will decrease more than by the amount $T_0T_1E_1Z$ transferred to producers – the amount measured by the area ZE_1E_0 will, again, add to social losses. The total social losses will be equal to the area FE_1C, i.e., they will rise by the area AFE_1E_0 (shaded trapezoid in Figure 1). That is, for the long-run social benefits from capital expansion and improvement in electricity industry made possible by the tariff increase, the society has to pay by giving up the amount of its welfare equal to the trapezoid AFE_1E_0.

The primary focus of in my thesis is estimating the size of this area.

Assuming the corresponding (quite short) line segments of D and MC as being well approximated by straight lines and basing the assumption about the value of MC at Q_1 on the information obtained from NERC, the welfare loss can be calculated from the estimated elasticity of electricity demand. Estimating the latter is the task of the empirical part of my thesis.

The electricity market under consideration includes both industrial and household segments. Demand elasticities are estimated for each segment, and changes in consumer and producer surpluses and in the social losses from planned increase in electricity tariffs are calculated.

The anticipated new level of electricity consumption is calculated as:

$$(3.1) \qquad Q_1 = Q_0 \cdot [1 + \varepsilon_{EPi} \cdot (\Delta T_{Eri})],$$

where Q_0 is the former level of electricity consumption[1]; $\Delta T_{Ej} = (T_1 - T_0)/T_0$ is the percentage change in electricity tariff in the j^{th} segment, j = {industrial, household}; and ε_{EPj} is the estimated price elasticity of electricity demand in j^{th} segment.

The loss of consumer surplus is then calculated as:

$$(3.2) \qquad LCS_j = (T_{j1} - T_{j0}) \cdot Q_{j1} + ½ \cdot (T_{j1} - T_{j0}) \cdot (Q_{j0} - Q_{j1}),$$

where T_{jt} is electricity tariff for the j^{th} segment in period t, t = {0, 1}, j = {industrial, household}; Q_{jt} is the amount of electricity consumed in the j^{th} segment in period t.

[1] For technical convenience, electricity consumption is denoted by 'Q' for industrial segment and 'Y' for households.

The part $(T_{j1} - T_{j0}) \cdot Q_{j1}$ of consumer surplus is transferred to the suppliers, whereas $\frac{1}{2} \cdot (T_{j1} - T_{j0}) \cdot (Q_{j0} - Q_{j1})$ represents the increase in the social loss in the j^{th} segment, estimation of which is the central concern of my thesis.

Two opposite effects determine the change of producers' surplus: it decreases because of the fall in the volume of electricity demand and rises due to increase in price per unit. The former is represented in Figure 1 by the areas ZE_0AF and $T_0T_1E_1Z$ respectively.

The 'fall' side can be approximated (assuming AF linear and horizontal, which is reasonable on this short interval) as:

$$LSS_j = (T_{j0} - MC) \cdot (Q_{j0} - Q_{j1}), \quad (3.3)$$

where MC stands for supplier's marginal costs.

Thus, total loss in supplier surplus from the drop in electricity demand is:

$$LSS = \sum_j LSS_j. \quad (3.4)$$

The supplier's gain from tariff increase can be calculated as:

$$GSS_j = (T_{j1} - T_{j0}) \cdot Q_{j1}, \quad (3.5)$$

which is in fact the amount extracted from consumer's surplus.

Thus, total gains in supplier surplus from increase in electricity tariffs are:

$$GSS = \sum_j GSS_j. \quad (3.6)$$

Hence, the *net* gain of electricity suppliers from increase in tariffs is:

(3.7) $$NG = GSS - LSS$$

The conventional theoretical setup of welfare analysis of the electricity market, presented above, serves as the basis for developing an empirical model for Ukraine. The Ukrainian context is discussed in the following chapter.

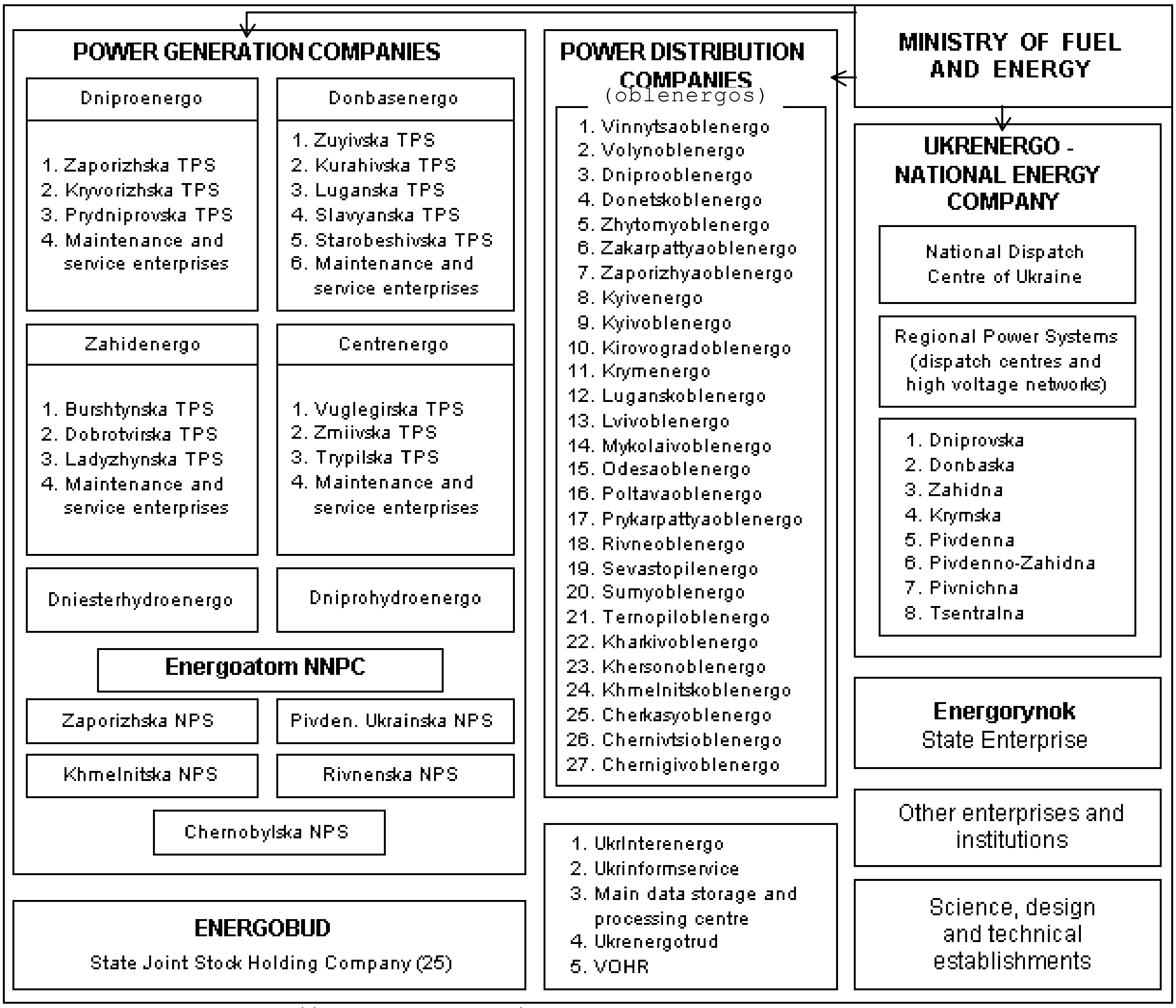
Chapter 4

THE UKRAINIAN CONTEXT

Generally, the market includes two major segments with significantly different price elasticities of electricity demand. They are: industrial consumers and residential users. The total physical size of the market is defined by the total installed capacity of 52 GW for electricity production.

The structure of electricity industry is summarized in the following chart:

Figure 2. Structure of Ukrainian energy sector



Source: http://www.imepower.com/index.shtml?nrg_overview#genco

In the generation stage, 2 hydro, 4 nuclear, 4 thermal power generation companies, and many combined heat & power stations (HPSs) operate in Ukraine. Also, there are small electricity producers (e.g. small hydro power stations). However, they constitute only an insignificant share in the total electricity production.[1]

In the distribution stage, the state enterprise NEC Ukrenergo operates high voltage (more than 220 kV) lines and interstate transmission of electricity as well as dispatches and controls the interstate power networks and all relevant infrastructures, including automation, control and communications systems, and others. Ukrenergo has eight regional divisions. Until recent times, it also included the State Enterprise "Energorynok" as a separate division, which executed electricity market operations.[2] In May 2000, Ukrainian government separated the functions of Ukrenergo and established "Energorynok" as the state enterprise responsible for the organization and maintenance of the functioning of the Wholesale Electricity Market (WEM); administration of WEM settlements and funds; purchase of electricity from electricity generators and electricity importers and wholesale supply of it to the distributing companies; in particular, – general organization and intermediation in the system of payment as laid down in Amendment to the Law of Ukraine on Electricity.[3]

In the distribution and supply stage, 27 local state power distribution companies (oblenergos) operate power transmission lines, transformer substations, electricity consumption meters and systems and other equipment.[4] They include 25 regional Oblenergos and 2 Oblenergos that serve cities such as Kyiv and Sevastopil. Oblenergos are licensed to distribute electricity, supply it at NERC-regulated tariffs, and provide related services to the customers. The licenses stipulate the

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[1] Source: http://www.imepower.com/index.shtml?nrg_overview#genco

[2] Source: http://www.imepower.com/index.shtml?nrg_overview#genco

[3] ibid. A detailed research in this field is currently done by my colleague, EERC MA student Kira Grozava.

[4] ibid

service territories, all consumers located in which must be served by oblenergos. As an alternative to oblenergos, independent suppliers operate in Ukraine, who are licensed to supply electricity at non-regulated tariffs and entitled to use oblenergos' networks for electricity distribution.[1] Electricity consumers are free to choose between oblenergos and independent suppliers.

The regulatory body is constituted by the Ministry of Fuel & Energy (Mintopenergo) and the National Energy Regulatory Commission (NERC).
Mintopenergo (established in 2000) is responsible for the implementation of government policy in Ukrainian energy sector, regulation and reformation of the power industry and energy market. Mintopenergo consists of four departments:

- Oil, gas and oil processing department;
- Nuclear power department;
- Coal department, and
- Energy department.[2]

NERC (established in 1994) is the main regulatory agency for the energy market. It implements government policy for the development and operation of the Wholesale Energy Market (WEM), oil & gas industries (in particular, tariff policy in electricity market); regulates energy sector monopolies, promoting competition in energy sector and protecting consumers' interests; provides licensing of electricity production, transmission, distribution, and supply; supervises the fulfillment of license conditions.[3] NERC's decrees regularly set the following tariffs:

- wholesale tariffs for electricity distribution;

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1 Source: http://www.imepower.com/index.shtml?nrg_overview#genco

2 ibid

3 ibid

- electricity tariffs for residential consumers.

The legal framework for electricity market operations is constituted by decrees of the President, Cabinet of Ministers, MFE, and NERC that specify the principles of activities and authority of the regulatory body, as well as the rights of other market agents.

The Resolution # 487 of Cabinet of Ministers of Ukraine of 21/05/1997 established the Wholesale Electricity Market.

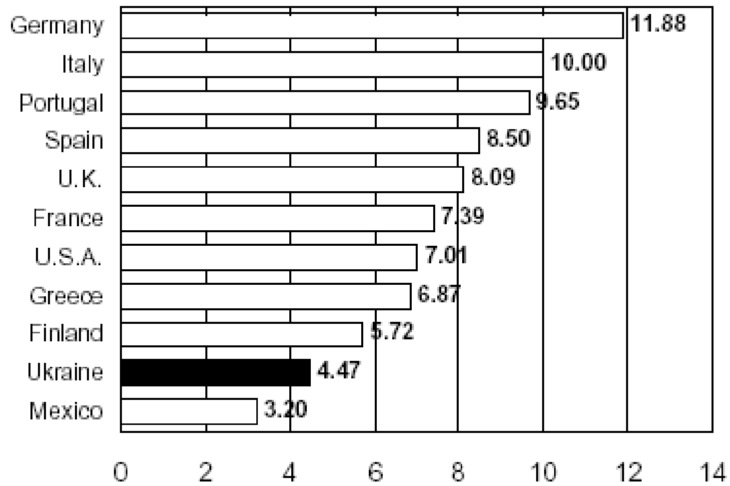
Most Ukrainian-specific problems of electricity are a legacy of the FSU.

First, in the FSU, for ideological reasons, electricity was treated as a public rather than a tradable good, and was provided at heavily subsidized prices. As a result, Ukraine started the transition with:

- electricity tariffs not covering costs of its production, and
- the common perception among residential users about electricity being an inalienable human right.

The extent of subsidizing can be gauged from the comparative international statistics for September 1997 presented in Figure 3 that illustrate this point, since the costs of producing electricity did not differ so sharply.

Figure 3.
Cost of Electricity to Consumers (U.S. cents / KWh)

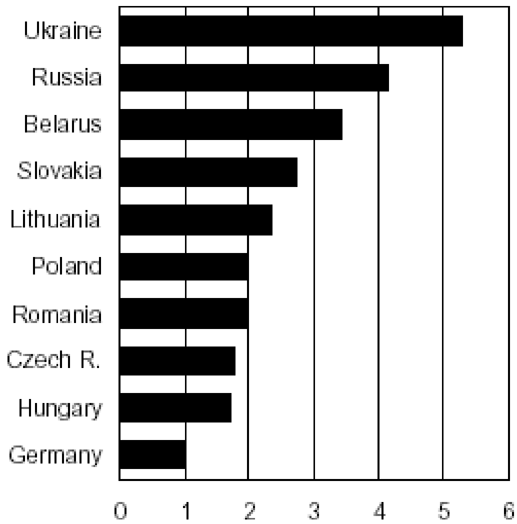


Source: Fincorp Invest (1997), p. 8.

Second, Ukraine inherited from the former USSR an energy-intensive industrial sector.

An international comparison (for September 1997) vividly suggests a high likelihood of electricity being currently overconsumed in Ukraine (Figure 4).

Figure 4.
Energy Consumption per Unit of GDP
(at Purchasing Power Parity, Germany = 1)



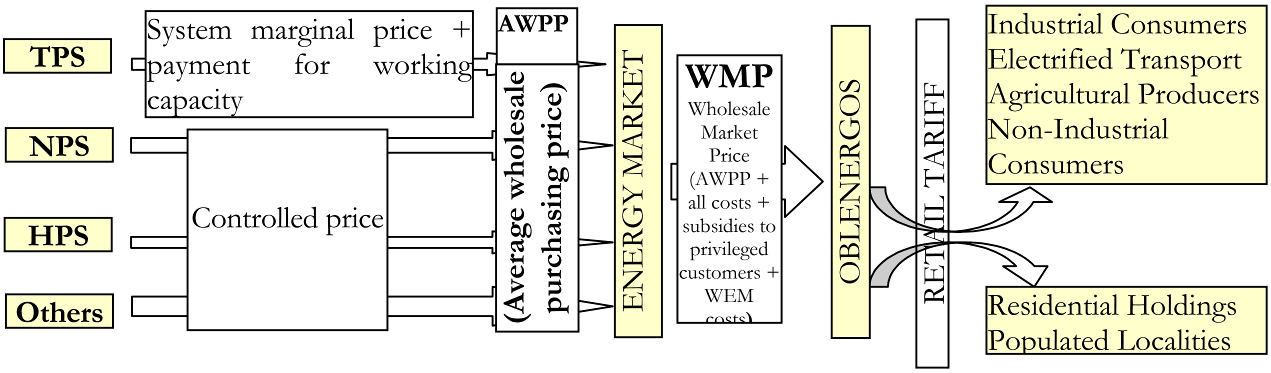
Source: Fincorp Invest (1997), p. 4.

However, it is widely claimed that vast increase in industrial electricity tariffs would drive too many firms out of business; thus causing irreparable harm to some industries.

The situation still remains problematic, even though the tariffs increased several times.

Another crucial issue is the price formation mechanism in Ukrainian electricity market, which can be schematically described as in Figure 5:

Figure 5. Price formation mechanism in Ukrainian electricity market



Source: reworked based on Kutsak (2001).

NERC controls most stages of this price formation process. Only thermal plants are allowed to compete.

The wholesale price consists of the following main types of components:

- "system marginal price" set by "Energorynok", which estimates expected demand for electricity and constructs the supply curve based on all power plants' bids, sets "system marginal wholesale prices" for electricity;
- payments for exploitation of electricity network;
- a number of indirect tax payments.

The retail tariffs are set according to the methodology adopted by NERC in 1998, which is classified as tariff setting on a cost-plus basis. The tariffs for consumers vary by the market segment and the level of voltage.

One large disadvantage of current price formation mechanism in Ukrainian electricity market is its extreme complicatedness, which seems hardly consistent with "mistakelessness" and efficiency.

Another drawback is that time-scheduled electricity tariffs for households (a variety of schemes of which is used in developed countries) are not developed in Ukraine.

Summarizing, the electricity market in Ukraine has a much shorter history than the electricity industry. The peculiarities of Ukrainian electricity market should be taken into account while applying the general economic models in the Ukrainian context. The most relevant of the Soviet legacy for my thesis is the highly distorted tariff structure, with below cost tariffs, in conjunction with high dependency of Ukrainian economic agents on electricity.

Chapter 5

DATA DESCRIPTION

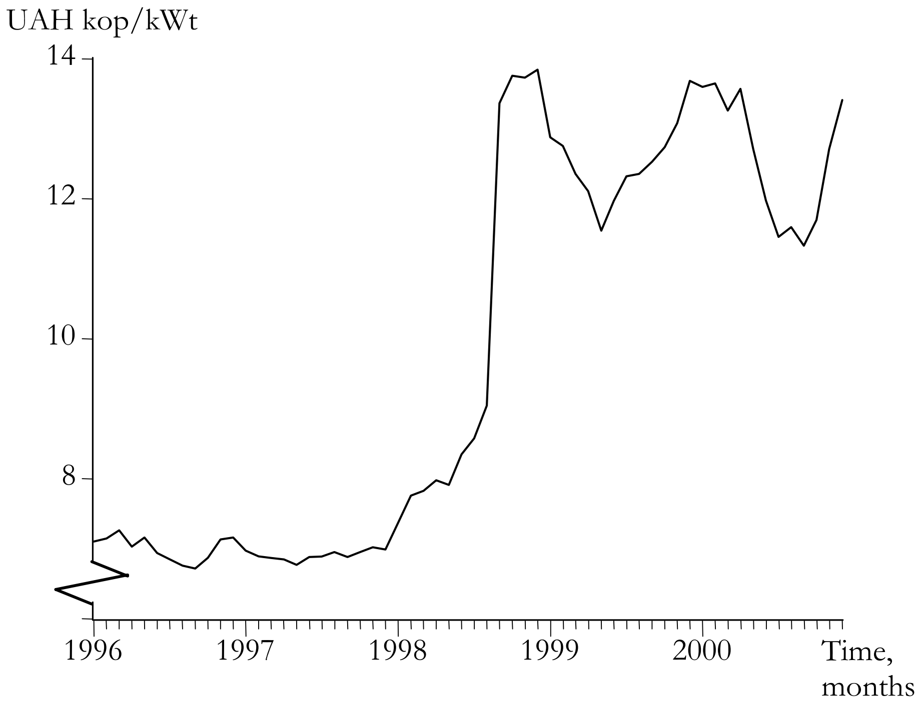
The basic data used in my research in the proposed thesis contains the following indicators:

1. Electricity tariffs for industries and households (per 1 kWh) for the period from 1996 to 2000 on monthly basis. Source: NERC.

The descriptive statistics of the data are presented in the Appendices 1 and 2. The graphical description is presented in the following figures:

For industrial tariffs:

Figure 6. Nominal Industrial Electricity Tariffs in Ukraine from 1996-2000

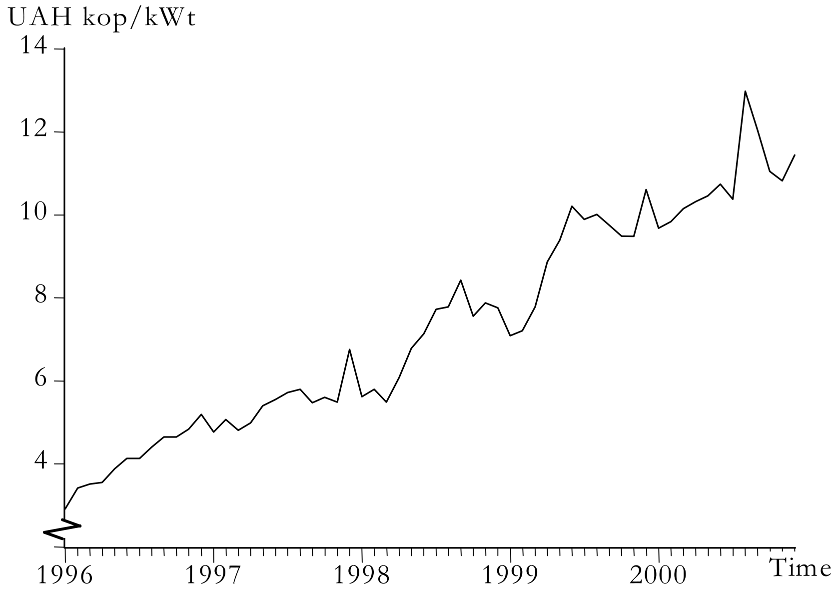


Data Source: NERC

In Figure 6, one can see that overall, the time path of industrial electricity tariffs is merely slightly increasing with moderate fluctuations, except for one sharp rise in August 1998. This rise can be naturally expected to correspond to the overall rise in the level of inflation (the date suggests attributing this to Russian crisis).

For household tariffs:

Figure 7. Nominal Household Electricity Tariffs in Ukraine from 1996-2000



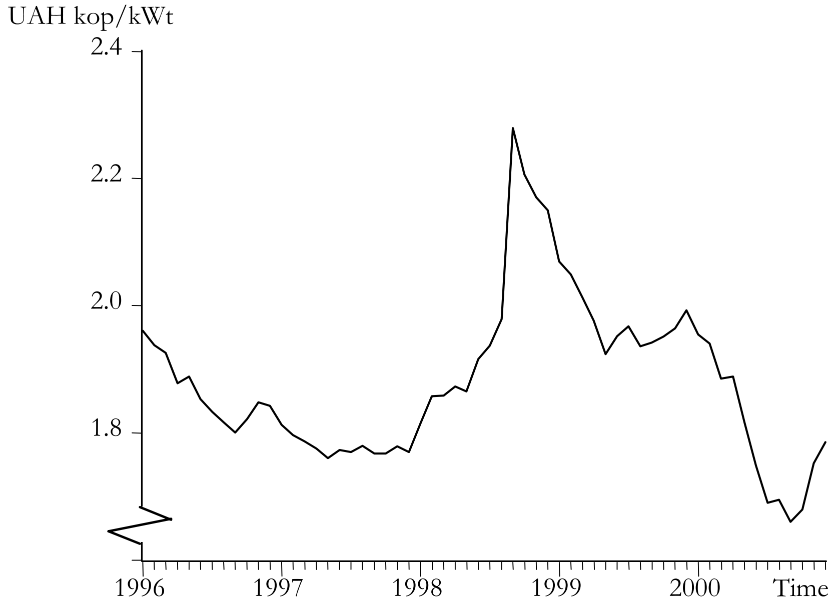
Data Source: NERC

Figure 7 shows a clear upward trend in residential electricity tariffs throughout the entire period considered with moderate fluctuations. The extent of the tariffs' increase is larger than that of the industrial tariffs.

A more meaningful interpretation of the path of electricity tariffs, however, can be drawn from considering *real* tariffs. For calculating the latter, the PPI and CPI indices for the correspondent periods were obtained from Derzhkomstat and Ukrainian State Ministry of Finance respectively. The descriptive statistics for the resulting real electricity tariffs are presented in the Appendices 3 and 4. The graphical description is presented in the following figures:

For industrial tariffs:

Figure 8. Real Industrial Electricity Tariffs in Ukraine from 1996-2000

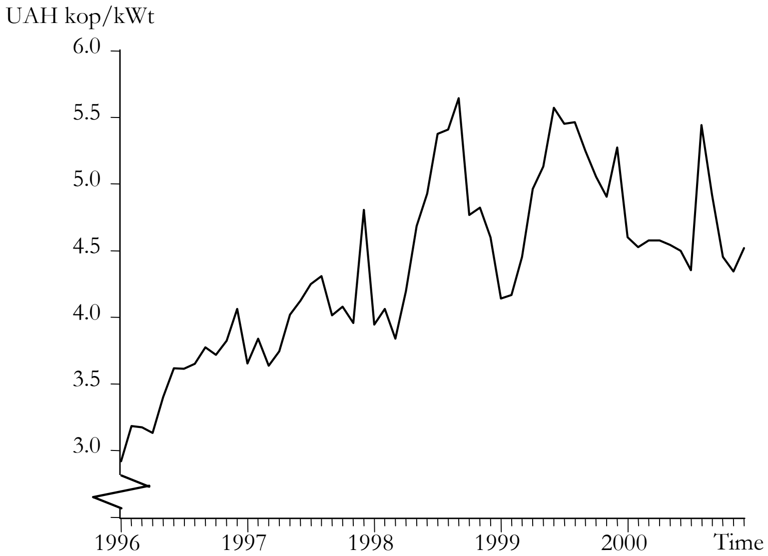


Data Source: NERC, own calculations

Figure 8 shows that, in real terms, industrial tariffs did not reveal an identifiable trend. This can be explained by the argument that, though NERC increased the tariffs several times, the rises in the PPI altered the pattern by neutralizing the increases to different degrees. The meaning of the latter statement should be clear from examining the part of the graph illustrating the tariff levels after the sharp spike noted above. During the Russian crisis of 1998, NERC sharply increased electricity tariffs, but the rise was then gradually absorbed by inflation. Unlike the nominal tariffs, which remained higher after the jump in August 1998, the real ones fell back to the previous levels. This must be because the PPI rose with a lag but remained higher afterwards.

For household tariffs:

Figure 9. Real Household Electricity Tariffs in Ukraine from 1996-2000



Data Source: NERC, own calculations

The previous argument applies here, as well. Most importantly, the upward trend of *real* household electricity tariffs is much weaker than that of nominal ones.

2. Physical (bln. kW) amounts of electricity consumed in each of the above segments for the period from 1996 to 2000 on monthly basis. Source: NERC.

The descriptive statistics of the data are presented in the Appendices 5 and 6. The graphical description is presented in the following figures:

For the industrial segment:

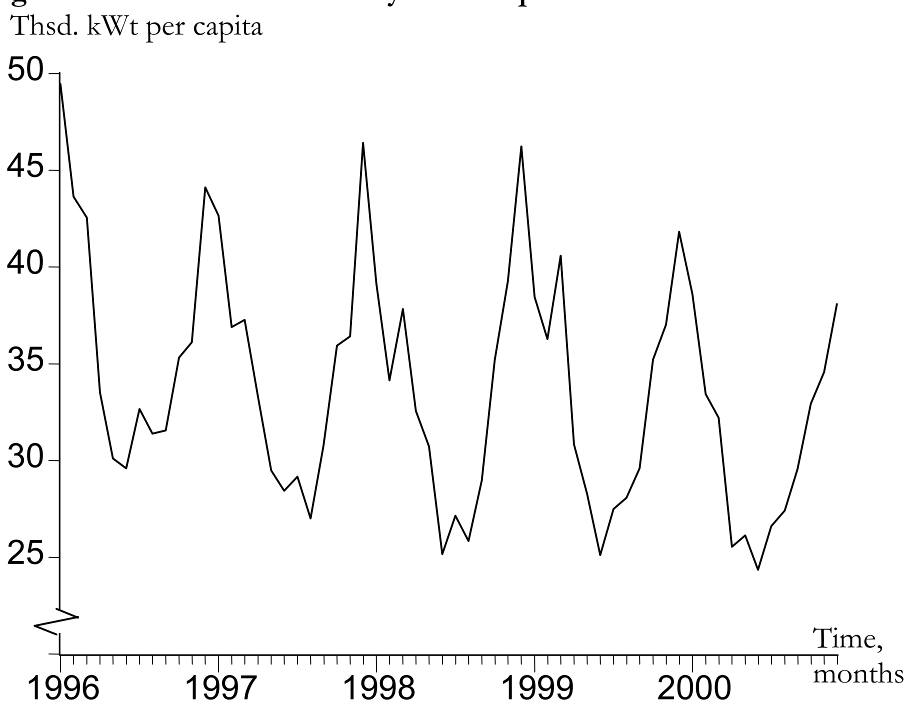
Figure 10. Industrial Electricity Consumption in Ukraine from 1996-2000

Data Source: NERC

A downward trend can be seen in this graph, which is consistent with qualitative reports from other sources referred to above. The only exception is increase in industrial electricity consumption in April – December 2000, which can be explained by economic growth in Ukraine in 2000.

For the household segment:[1]

Figure 11. Household Electricity Consumption in Ukraine from 1996-2000



Data Source: NERC, http://upop.irex.ru/display_eco.asp, own calculations

A clear seasonal pattern of electricity consumption (expected ex ante) with peak and off-peak seasons can be seen in Figure 11. Therefore, in the econometric estimation, I have to control for seasonality.

3. Index of real industrial production for the period from 1996 to 2000 on monthly basis (% to 1990). Source: NBU.

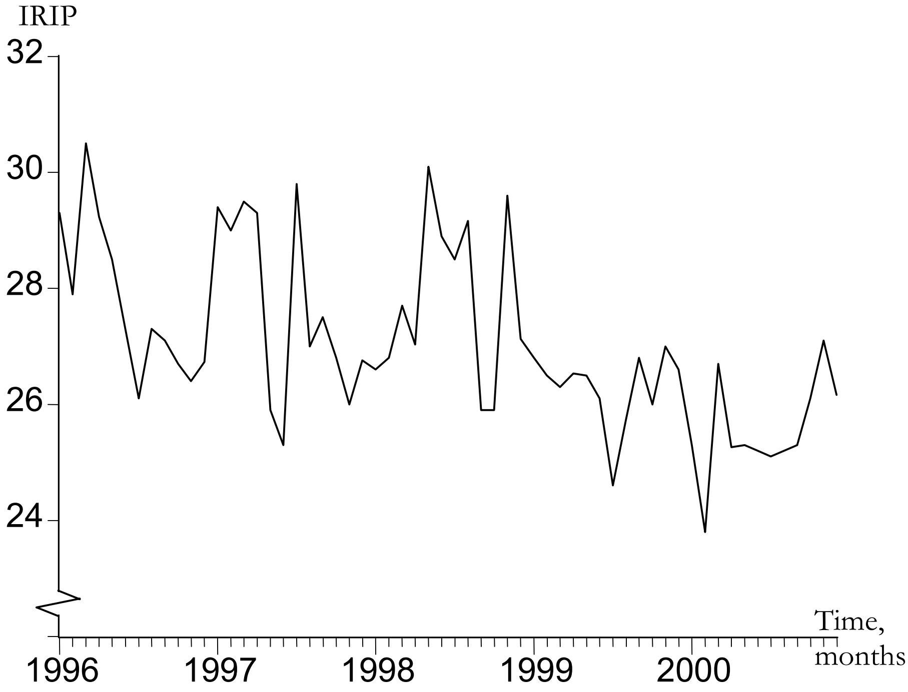
The descriptive statistics of the data are presented in the Appendix 7.

---

[1] In per capita terms (the data on population obtained from statistical server on Ukraine: http://upop.irex.ru/display_eco.asp)

The graphical description is presented in the following figure:

Figure 12. Index of Real Industrial Production[*] in Ukraine from 1996-2000



[*] Base year: 1990 = 100

Data Source: NBU

A slight downward trend and modest fluctuations can be observed in the graph, except the rise in recent months, explained, again, by economic growth in 2000.

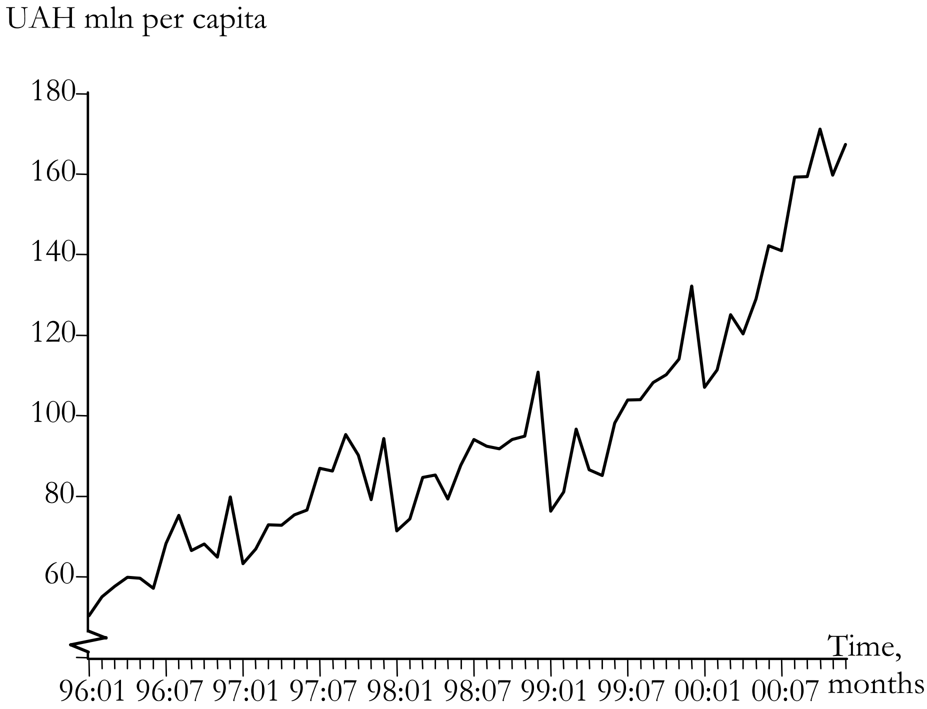
4. Household Money Expenditures (UAH mln per capita) for the period from 1996 to 2000 on monthly basis.[1]

The descriptive statistics of the data are presented in the Appendix 8:

[1] Sourse: http://upop.irex.ru/display_eco.asp

The graphical description is presented in the following figure:

Figure 13. Real Household Money Expenditures (UAH mln per capita) in 1996-2000



Data Source: http://www.bank.gov.ua/Macro/index.htm

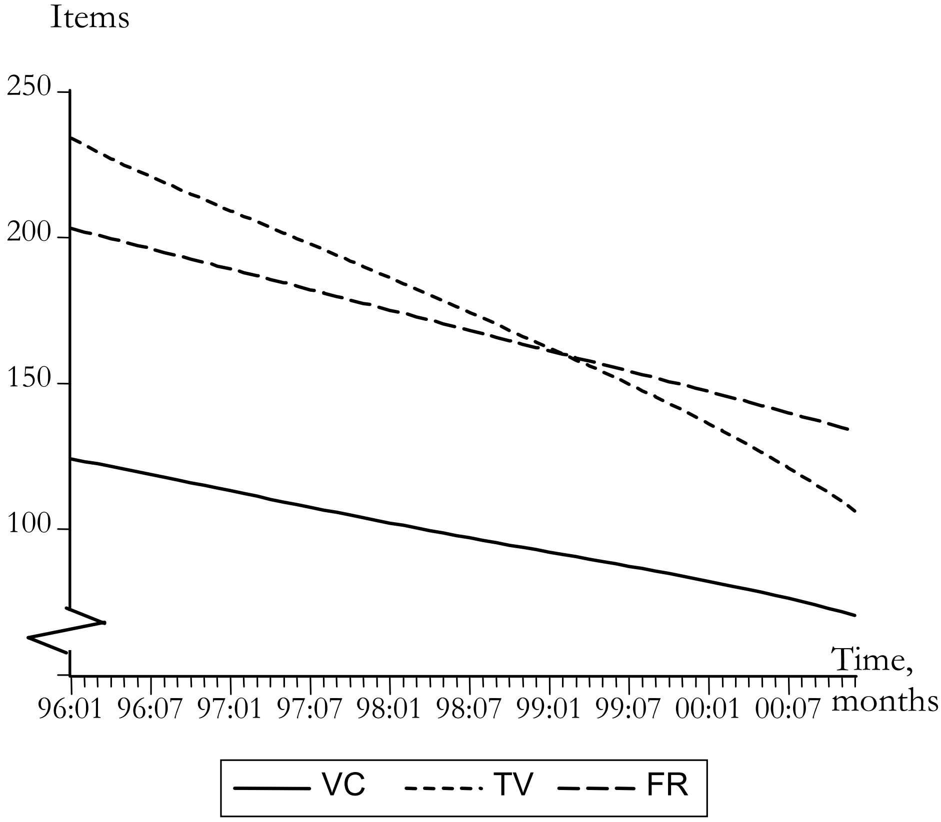
An upward trend in per capita household money expenditures is obvious from the graph.

5. Possession of electricity-using equipment per 1000 population (items, adjusted to beginning of month): freezers, TV-sets, vacuum cleaners. Sourse: Derzhkomstat.

The descriptive statistics of the data are presented in the Appendix 9.

The graphical description is presented in the following figure:

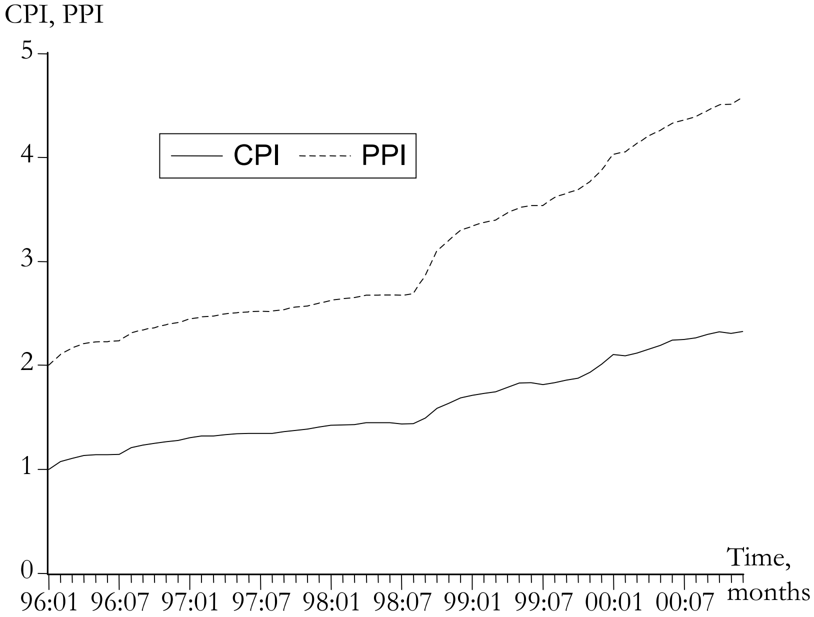
Figure 14. Possession of Electricity-Using Equipment by Households (per 1000 population) in Ukraine from 1996-2000



Data Source: Derzhkomstat

Technically, the data on CPI and PPI are used in the thesis to assess economic variables in real terms (wherever this is done, the references are made in the text). The graphical representation of CPI and PPI is shown in the following figure:

Figure 15. Monthly CPI and PPI in Ukraine from 1996-2000



Data Source: Derzhkomstat

The summary of the descriptive statistics for the above data is presented in the below table:

Table 1. The Descriptive Statistics for Variables Used in the Thesis (Data for Ukraine from 1996 to 2000][1]

Sample: 1996:01 2000:12
Included observations: 60

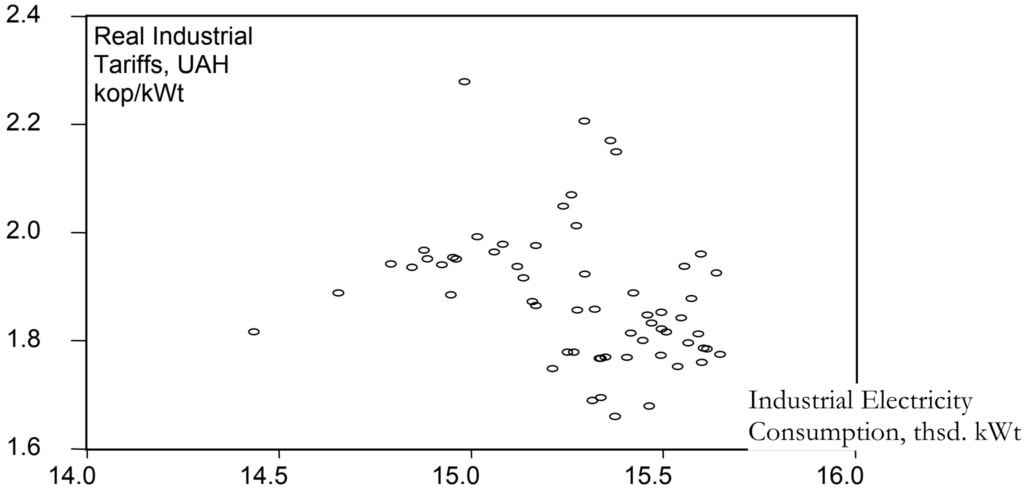
Variable	Abbreviation	Mean	Median	Max	Min.	Std. Dev.
Electricity Tariffs for Industries	IT	9.795130	8.459966	13.84135	6.716737	2.834191
Electricity Tariffs for Households	HT	7.307500	7.115000	12.98000	2.920000	2.600556
Real Electricity Tariffs for Industries	RIT	1.881238	1.861747	2.279181	1.659989	0.127175
Real Electricity Tariffs for Households	RHT	4.365917	4.347475	5.644520	2.920000	0.673136
Physical (bln. kW) Amounts of Electricity Consumed in the Industrial Segment	Q	4466202.	4535872.	6251668.	1855075.	1079001.
Physical (bln. kW) Amounts of Electricity Consumed in the Residential Segment	Y	33.73818	33.12238	49.45418	24.35182	6.031629
Index of Real Industrial Production	IRIP	27.01033	26.74500	30.50000	23.80000	1.518124
Household Monthly Money Expenditures	X	94.55408	87.34217	171.2355	50.27847	29.79346
Possession of Electricity-using Equipment Per 1000 Population:						
Freezers and Refrigerators	FR	168.5225	168.5689	203.0000	133.3365	20.45959
TV	TV	173.5417	175.1195	234.0000	106.1755	36.29609
Vacuum Cleaners	VC	97.64683	97.30256	124.0000	70.28947	15.39160

To avoid spurious regression, I take into account time trends in the paths of population expenditures and possession of "white goods". Indeed, the latter decreased and the former increased on average over the entire period in study. I use those variables in the regression in *detrended* form. The latter is obtained by regressing the original variables on time and substituting the residuals into the main regression.

To offer a preliminary evaluation of the relationship between electricity consumption and tariffs, I plot those in the following graphs:

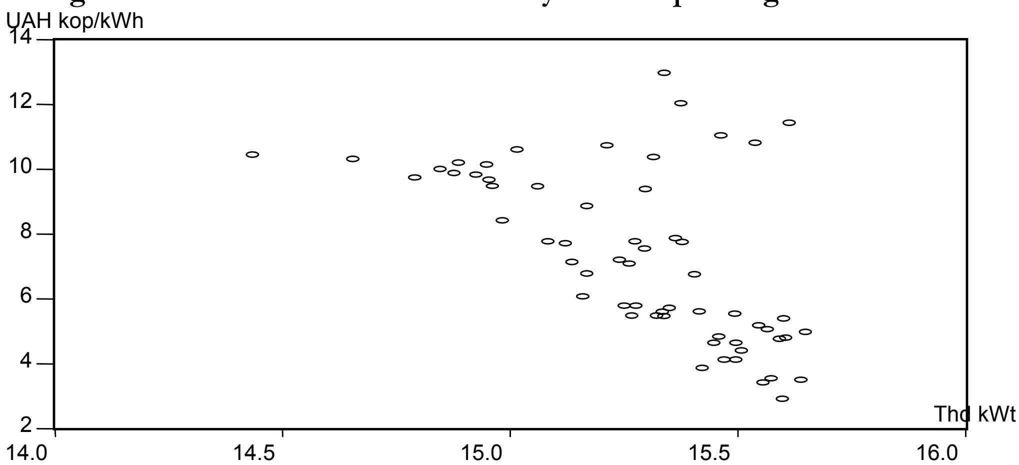
[1] Data sources for the variables are: NERC, Derzhkomstat, UEPLAC, NBU. See also references in the above text.

Figure 16. Plot of Industrial Electricity Consumption against Tariffs



Data Source: own calculations

Figure 17. Plot of Residential Electricity Consumption against Tariffs

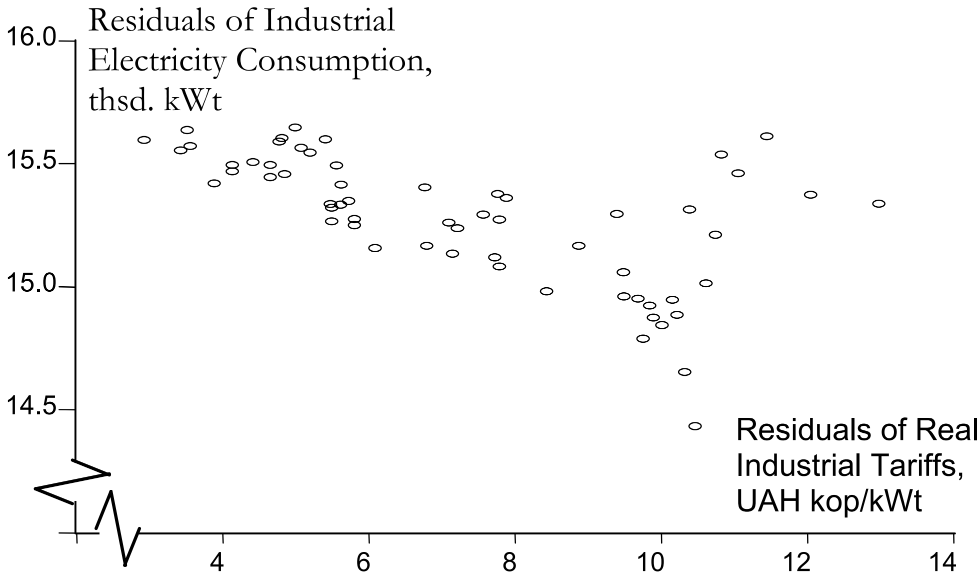


Data Source: own calculations

An *inverse* relationship is easily observed in both Figure 16 and Figure 17, from which only seven points deviate, the latter fact being naturally attributed to random disturbances.

Even stronger is the inverse relationship between the *residuals* from regressing of both variables on the set of other regressors used in the subsequent econometric model for household segment:

Figure 18. Residual Plot of Residential Electricity Consumption against Tariffs



Data Source: own calculations

Regressing the studied variables on the set of all other regressors is aimed at ruling out all the effects on electricity consumption except that of tariff changes (and, of course, of random disturbances). The technique implies that the correlation between the residuals of the two studied series are explained by the dependence of the consumption on the tariffs and by random disturbances, the latter being assumed minor. Thus, examining the above residual plot is more insightful.

Based on the data described above, I estimate an empirical model of electricity demand in each of the considered segments to obtain estimates of the corresponding price elasticities.

Chapter 6

EMPIRICAL MODEL

Estimating the Elasticity of Industrial Electricity Demand

Analogically to Bjorner et. al. (1998), I assume that all enterprises in each sector:

- conceive the prices of all production factors as given (exogenous);
- minimize the costs of production.

A further assumption is a two-input CES production function, the inputs being, conventionally, electricity and the 'other inputs' composite. The electricity demand function can be derived from the production function. Ukrainian data on industrial electricity consumption is available in aggregated form for Ukrainian industrial sectors.

The following denotations are used in further exposition:

Q_{Et} – the amount of electricity (kW) consumed in period *t*;

VA_t – the value added in industrial sector, UAH (measured in prices of the corresponding year);

T_{Et} – the price (tariff) for electricity in period *t*;

PPI_t – the producer price index in period *t* (which serves as a deflator for VA_t);

ε_t – the error term.

The electricity demand function is, then, approximated by the following equations:

$$\text{(6.1)} \qquad Log(Q_{Et}) = \alpha + \beta_1 \cdot Log(\frac{VA_t}{PPI_t}) + \beta_2 \cdot Log(\frac{T_{Et}}{PPI_t}) + f(t) + \varepsilon_t,$$

where $f(t)$ is a function capturing all exogenous factors which can be summarized as 'technological change'.

Bjorner's specification unambiguously suggests (as well as the intuitive logic) that the significant factors that determine industrial electricity demand are:

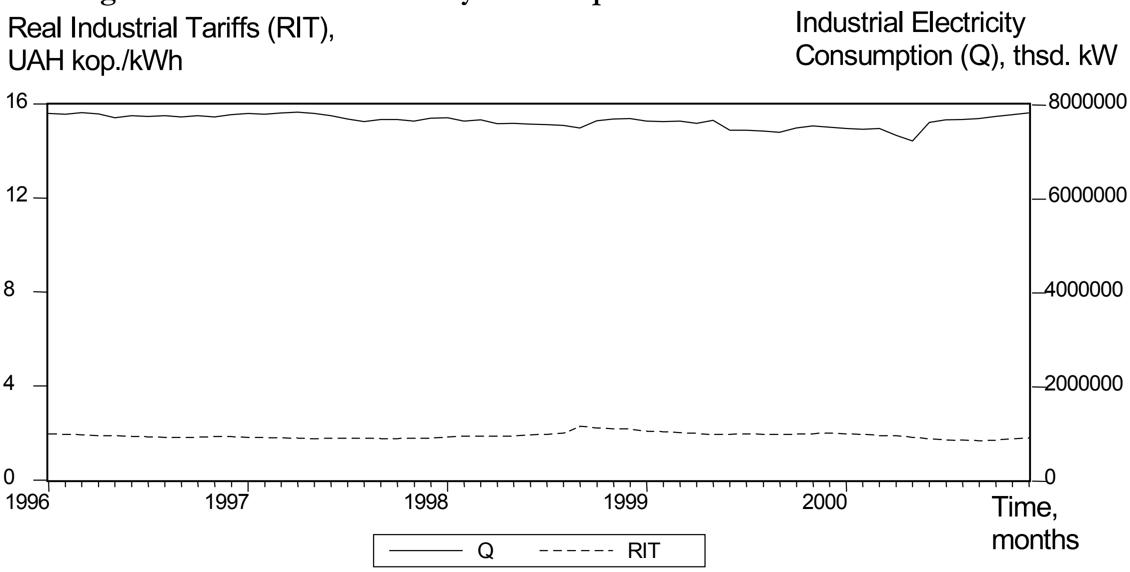
- (Real) industrial electricity tariffs;
- Dynamics of real industrial production (since demand for electricity is a derived demand).

In my thesis, the equation specification is based on this suggestion and is justified to the specifics of Ukrainian electricity market and estimation framework.

The slope β_1 in the regression is the elasticity of industries' demand on composite factor of production, and β_2 is the price elasticity of industrial electricity demand in question.

Preliminary regression has shown that the dependence of $Log(Q_{Et})$ on time was low and insignificant, which was also intuitively clear from the graphical inspection:

Figure 19. Industrial Electricity Consumption and Real Industrial Tariffs



Source: Own Composition

Both real industrial tariffs and industrial electricity consumption exhibited only minor fluctuations in a narrow range during the entire period in study. Hence, I do not include time factors in the final regression.

For the (technical) purpose of removing autocorrelation, I included an AR(1) term in the RHS of the estimated equation.[1]

Based on all set above, the final regression equation is:

(6.2) $$Ln(Q_{Et}) = \alpha + \beta_1 \cdot Ln(IRIP_t) + \beta_2 \cdot Ln(RIT_t) + \rho \cdot AR(1) + \varepsilon_t,$$

where $IRIP_t$ is the index of real industrial production, RIT_t is the real industrial tariff at period t, and $AR(1) = \hat{e}_t$ is the autoregressive term ($\hat{e}_t$ are obtained by

[1] Preliminary regression suggested that inclusion of AR(1) term was the optimal (with respect to the model's explanatory power) way to avoid the problem of autocorrelation.

iterative substituting ε_t into the regression in place of $\hat{\varepsilon}_t$ and reestimating the equation until ε_t and $\hat{\varepsilon}_t$ converge).

The model for residential holdings' electricity demand.

The second part of the task is to estimate the elasticity of electricity demand by residential holdings. In specifying the model equation of electricity demand, I base on the paper by Hsiao and Mountain (1985), who suggest a model for estimating the income elasticity of households' electricity demand

In their model, log of household electricity consumption is regressed (including intercept) by OLS on log of electricity price, log of "other goods" price, log of disposable income, and set of dummies for possession of electricity-using appliance.

This specification (as well as the intuitive logic) suggests that the significant factors that determine electricity demand by households are: price (tariff) for electricity (relative to other goods), incomes, and possession of electricity-using equipment. The specification of the equation in my thesis is based on this suggestion and is justified to specifics of Ukrainian electricity market and estimation framework. In particular, aggregated Ukrainian data on the explanatory variables is used in my model (in per capita terms).

Since Hsiao and Mountain (1985) use a 1-period cross-sectional data, electricity and 'other goods' prices are fixed in their model. To estimate *price* elasticity, however, one needs to incorporate *dynamics* of electricity price for several periods. Also, since my model's focus is on the price-demand aspect rather than on income-expenditure one, it is reasonable to use the *relative* electricity price on the right-hand side with CPI standing for 'other goods' price. (Technically, the *real* electricity tariff is calculated by division of the nominal one by the CPI and is used as a regressor). In line with this argument, real income is used in the model.

A (quite common) problem should be expected with using income statistics. The latter is formed largely based on people's reportings. Since levels of income influence the amount of taxes people have to pay, they have an incentive to underreport their incomes. It is reasonable to expect this underreporting to be widespread, especially given a well-known large size of shadow economy in Ukraine. Therefore, it is reasonable to doubt the reliability of data on incomes. More objectively observable and, thus, more reliable is data on household expenditures. Hence, I use it in my thesis.

Furthermore, the peculiarities of Ukrainian electricity market (legacy of the former Soviet Union tradition discussed in the above chapters) suggest one to expect some 'autonomous' level of electricity consumption. To account for this factor, one needs to use a linear demand regression specification (in levels), which yields a meaningful intercept.

To calculate elasticity at period t (I will be interested in the last period available), I use the conventional formula[1]:

$$\varepsilon_{EPt} = \frac{\partial Y_t}{\partial P_{E\_real\_t}} \cdot \frac{P_{E\_real\_t}}{Y_t} = \gamma \cdot \frac{P_{E\_real\_t}}{Y_t}, \quad (6.3)$$

where γ is the regression coefficient of the real electricity tariff.

Besides, as household electricity demand pattern has clear seasonal features, dummies for peak and off-peak seasons should be included in the regression.

Since people's plans of most household activities involving electricity consumption are subject to habits, electricity consumption must adjust to tariff changes with a slight lag. Even a stronger tendency of residential electricity

[1] Gujarati (1995). – p. 178

consumption to lag by 1 month should be, logically, expected in the wake of the announcement of the forthcoming tariff change, so that a large part of household decisions is based on the previous month's electricity tariff value. The above considerations suggest using a one-period lag of the real residential electricity tariff in the final regression.

Summarising, the proposed electricity demand regression equation is:

$$(6.4) \qquad Y_t = C + \gamma \cdot P_{E\_real\_t-1} + \beta \cdot X_t + \sum_{j=1}^{M} a_j D_j, + \lambda_1 \cdot PEAK + \lambda_2 \cdot OFF\text{-}PEAK + \varepsilon_t$$

where (for each period [month] t): Y_t is electricity consumption; $P_{E\_real\_t-1}$ is real electricity tariff; D_j is per capita possession of electricity-using appliance of the type j (total M types considered); X_t stands for the per capita household's income; M – number of the types of electricity-using appliance considered; PEAK and OFF-PEAK are seasonal dummies; C, γ, β, λ_1, λ_2, and a_j (j = 1,M) are the parameters to be estimated.

Examining preliminary regressions suggested the existence of hysteresis-like effects of some past levels of residential electricity consumption on its current level. It is necessary to control for those effects to avoid serial correlation. The argument of habits and delays in realizing plans suggests that the one-period lag of electricity consumption be the most influential. Also, the 12^{th} lag, i.e. the one which reflects the long-run household consumption path[1], is important. The latter, in its turn, was affected by the preceding, 13^{th}, lag for the reason described above. Summarizing, the above considerations suggest inclusion of Y(-1), Y(-12), and Y(-13) in the final regression.[2] This specification is consistent

[1] It corresponds to the same month of previous year, thus being net of seasonal impact.

[2] As shown below, estimation confirmed that this specification is free of autocorrelation and heteroscedasticity and provides a better fit than other specifications with different number of lags.

with the traditional way of dealing with seasonal regularities in data presented in Johnston and DiNardo (1997)[1].

Furthermore, preliminary regressions exhibited high multicolinearity between the variables for all types of electricity-using equipment. This suggested me to include only the possession of refrigerators/freezers (that have the highest explanatory power) into the final regression.

Hence, the final regression equation for residential electricity demand is:

$$(6.5) \qquad Y_t = C + \gamma \cdot P_{E\_real\_t-1} + \beta \cdot X_t + a \cdot FR, + \lambda_1 \cdot PEAK + \lambda_2 \cdot OFF\text{-}PEAK + \\ + \delta_1 \cdot Y(-1) + \delta_2 \cdot Y(-12) + \delta_3 \cdot Y(-13) + \varepsilon_t$$

where FR is per capita possession of freezers and refrigerators by Ukrainians; and δ_1 .. δ_3 are the parameters associated with lags of Y.

γ is the parameter of interest – the price elasticity of household electricity consumption. Ex ante, I expect a negative sign, as electricity is an ordinary good. Given a *restricted* monopolistic supply, the demand elasticity is expected to be less than unitary.

The expected sign of β is also positive, because electricity is a normal good.

Naturally, λ_1 is expected to be positive and λ_2 – negative.

Finally, the intercept is expected to be positive and comparable to the actual average level of electricity consumption.

---

[1] Based on discussion of AR(1)SAR(12) specification – Johnston and DiNardo (1997), p.235.

Chapter 7

RESULTS

Estimation Results for Industrial Segment

For the (technical) purpose of removing autocorrelation, I included an AR(1) term on the RHS of the equation estimated.[1]

The estimated electricity demand equation for industrial sector is:

(7.1)
$$\ln Q_t = \underset{(0.86)}{16.317} + \underset{(0.01)}{0.011}\cdot \ln IRIP_t - \underset{(0.37)}{0.710}\cdot \ln RIT_t + \underset{(0.08)}{0.813}\cdot AR(1)$$

Inspection of the correlogram of residuals clearly suggests that the model is free of autocorrelation. The same conclusion is confirmed by Breusch-Godfrey Serial Correlation LM test. The Augmented Dickey-Fuller Unit Root Test rejects the hypothesis of unit root at all reasonable significance levels. The hypothesis of heteroscedasticity is also rejected, according to White Heteroskedasticity Test. (Appendix 13).

The regression coefficients of the explanatory variables should be interpreted as representing elasticities of industrial electricity demand on real production and electricity tariff respectively. The latter elasticity (– 0.71) is of primary interest in the subsequent analysis.

---

[1] The estimation output for electricity demand in the industrial segment is presented in the Appendix 10.

Estimation Results for Residential Segment

As mentioned in the Data Description chapter, technically, *detrended* data on freezer possession should be used in the regression.

Preliminary regression yielded a statistically insignificant coefficient at the income (expenditures) variable X_t, which suggested exclusion of the latter from the regression. Intuitively, as long as the actual levels of electricity consumption are close to the "autonomous" level, the part of it which depends on income (expenditures) constitutes only a small proportion in the actual levels of electricity consumption. Visual inspection of the graphical representation of the path of income (expenditures) also suggests only a little correlation with electricity consumption. Besides, it is natural to expect multicolinearity of X_t with the possession of refrigerators.

The estimated electricity demand equation for households is:[1]

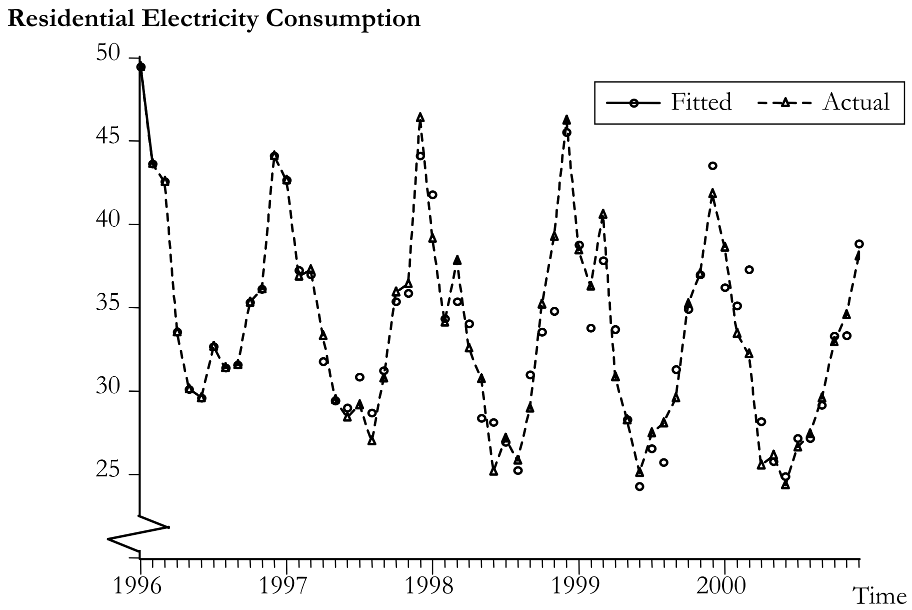
$$(7.2)\quad \underset{}{Y_t} = \underset{(6.93)}{20.435} - \underset{(0.71)}{1.296}\cdot P_{E\_real\_t-1} + \underset{(2.07)}{3.307}\cdot FR_t + \underset{(2.87)}{2.869}\cdot PEAK_t - \underset{(1.02)}{2.659}\cdot OFF\text{-}PEAK_t +$$

$$+ \underset{(0.14)}{0.336}\cdot Y(-1) + \underset{(0.11)}{0.678}\cdot Y(-12) + \underset{(0.12)}{0.451}\cdot Y(-13)$$

High $R^2 = 89.53\%$ means that the model provides a good fit. This can also be visualized by graphing the actual and fitted residential electricity consumption paths as follows:

[1] The estimation of the (corrected) regression equation for households' electricity demand yields the output presented in the Appendix 11.

Figure 20. Actual and Fitted Residential Electricity Consumption Paths in 1996-2000.



Data Source: NERC, own calculations

Inspection of the residuals correlogram clearly suggests that the model is free of autocorrelation. The same conclusion is suggested by Breusch-Godfrey Serial Correlation LM test. The Augmented Dickey-Fuller Unit Root Test rejects the hypothesis of unit root at all reasonable significance levels. The hypothesis of heteroscedasticity is also rejected, according to White Heteroskedasticity Test. (Appendix 14).

The regression coefficients should be interpreted as follows:

The 'autonomous' electricity consumption C = 20.435 means that, under zero real electricity tariff for households, zero incomes, and absence of refrigerators/freezers, the desired level of electricity consumption by population would be 20.435 kW/month per capita in non-peak and non-off-peak seasons.

The positive sign of the intercept is consistent with the fact that electricity is a "good" rather than a "bad".

In the peak (winter) seasons, 2.869 kW/month per capita add to the autonomous electricity demand on average, whereas in off-peak (summer) seasons, the autonomous electricity demand decreases on average by 2.659 kW/month per capita. The signs of the parameters are, again, meaningful.

If the per capita possession of freezers and refrigerators by Ukrainian population increases by 1, this will raise the average residential electricity demand by 6.74 kW/month per capita (consistently with prior expectations).

Finally, the coefficient which is of interest in this thesis $\gamma = -2.85$ is to be used in calculating elasticity of residential electricity demand. The negative sign conforms to the prior expectations – it means that the demand is downward sloping, as should be expected.

To calculate the elasticity itself, the conventional formula is used:

$$\text{(7.3)} \qquad \varepsilon_{EPt} = \frac{\partial Y_t}{\partial P_{E\_real\_t}} \cdot \frac{P_{E\_real\_t}}{Y_t} = \gamma \cdot \frac{P_{E\_real\_t}}{Y_t}$$

For 2001:11, for example, the elasticity in question is:

$$\text{(7.4)} \qquad \varepsilon_{EP2000:12} = \gamma \cdot \frac{P_{E\_real\_2000:12}}{Y_{2000:12}} = -1.296 \cdot \frac{4.53}{36.23} = -0.1620$$

So, based on the data for 1996-2000, a 1% increase in electricity tariffs for households should have been expected to drive their electricity consumption down by 0.16%. The elasticity is significantly less than unitary, which means that the monopolistic electricity supplier, if unregulated, can charge his price (tariff) with quite high mark-up.

The full set of estimated residential electricity demand elasticities is presented in Appendix. 12.

Chapter 8

DISCUSSION OF RESULTS

The estimated elasticities in both electricity market segments are less than unitary, which allows for the possibility of supplier's gain by increasing price.

Comparison of the elasticities of industrial and residential electricity demands also suggests a possibility of cross subsidizing of industries by households, as the latter have lower demand elasticities. This finding is consistent with typical situation recognized worldwide. But it is quite surprising for Ukraine at first sight, since the opposite situation here is well-known: that industries cross-subsidize households[1].

No surprise is found, however, if one acknowledges the fact that cross-subsidization in favor of industries occurs only when tariffs for the latter are lower than for households. In an unregulated market, this situation is automatically assured by residential demand being less elastic than industrial one, enabling a supplier with market power to price discriminate. On the other hand, when the market is regulated through price setting, the difference in tariffs may not depend on the difference in elasticities. Thus, cross-subsidization can be well *forced* to favor population at the expense of industries even without much considerations about relative demand elasticities. The latter situation is actually the case in Ukraine.

Having estimated electricity demand elasticities, it is possible now to estimate welfare consequences of a tariff increase.

---

[1] This fact can be easily verified by comparing the actual electricity tariffs for industries and households: the former are subject to higher tariffs than the latter. (Data Source: NERC)

The government has announced its current plans to increase electricity tariffs for industrial customers on average by 8% and for residential holdings by 20%.[1] The reason for this increase is the inclination revealed by the government to approve the demand by industrial producers to that effect.

According to the above estimation, implementation of the above increase at the beginning of 2002 would have the following implications.

The new level of electricity consumption by industries would be:

$$Q_1 = Q_0 \cdot [1+\varepsilon_{EPi} \cdot (\Delta T_{Eri})] \quad (8.1)$$

$$Q_1 = 5{,}392{,}020 \cdot [1 - 0.7095 \cdot (0.08)] = 5{,}085{,}970 \text{ (thsd kW)} \quad (8.2)$$

The new level of per capita electricity consumption by households would be[2]:

$$Y_1 = Y_0 \cdot [1+\varepsilon_{EPh} \cdot (\Delta T_{Erh})] \quad (8.3)$$

$$Y_1 = 36.23 \cdot [1 - 0.162 \cdot (0.20)] = 35.06 \text{ (kW)} \quad (8.4)$$

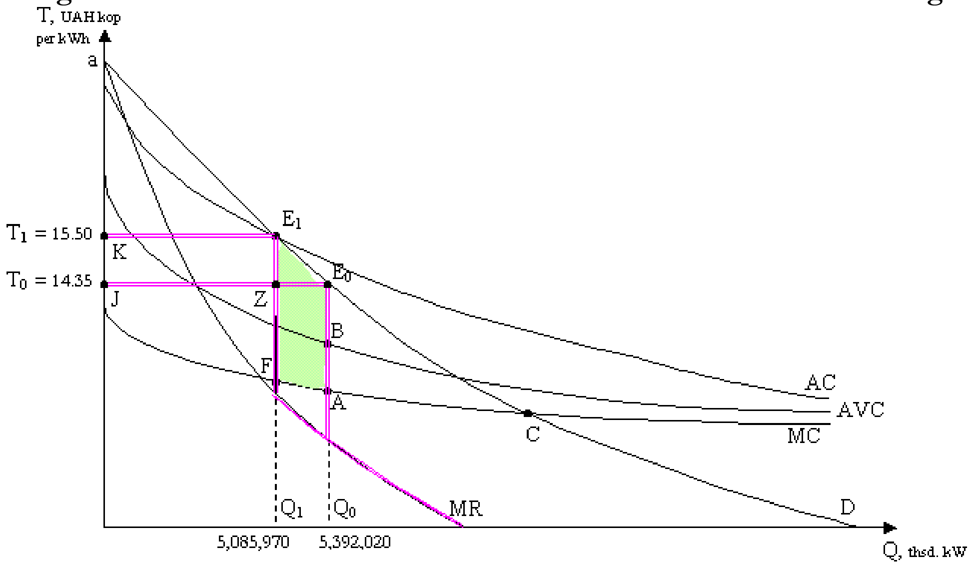
The resulting figures are correspondingly marked in the following graph (tariffs are included in nominal terms):

---

1 Infobank. (2001). Newsletter. Nov21-1

2 A usual *ceteris paribus* assumption is made in this calculation: per capita expenditures and per capita possession of electricity are implicitly assumed to not change (reasonable in the short run); the calculations are conducted for an average (non-peak and non-off-peak) season.

Figure 21. Welfare Effects From an Increase in Industrial Tariff Ceiling



Source: own composition

In Figure 21, an increase in electricity tariff for industries from 14.35 to 15.50 UAH kop/kWh leads to a drop in monthly electricity consumption from 5,392,020 to 5,085,970 thsd kW.

Hence, the loss in industrial consumers' surplus would be equal to the area:

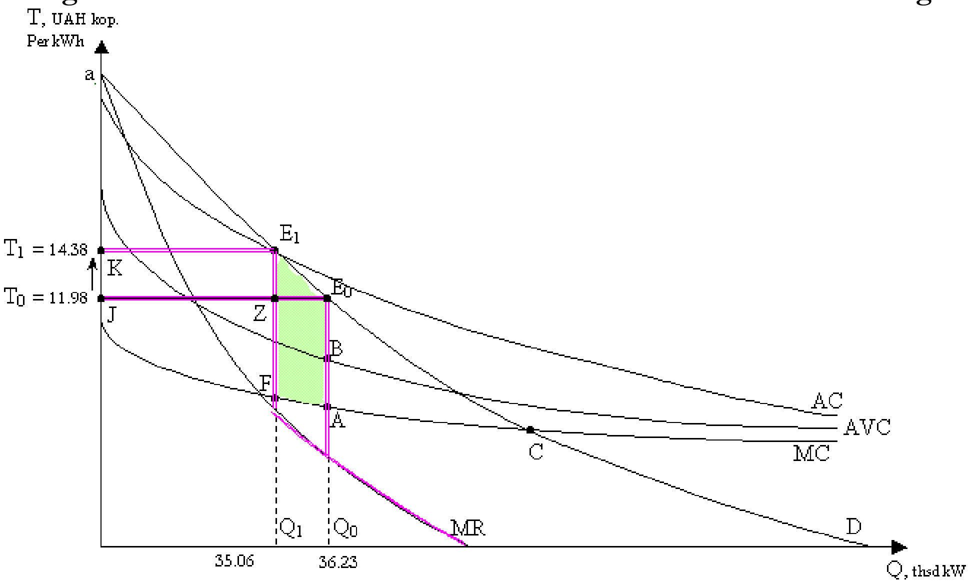
(8.5) $LCS_I = (K - J) \cdot Q_1 + ½ \cdot (Q_0 - Q_1) \cdot (T_1 - T_0)$, or

(8.6) $LCS_I = 5{,}085{,}970 \cdot (155.0 - 143.5) + ½ \cdot (5{,}392{,}020 - 5{,}085{,}970) \cdot (155.0 - 143.5) =$

$= 58{,}488{,}655 + 1{,}759{,}788 = 60{,}248{,}443$ UAH (or 60,248.44 thsd UAH).

58,488,655 UAH of it will be transferred to the suppliers, whereas 1,759,788 UAH represent the increase in the social loss in the industrial sector.

Figure 22. Welfare Effects From Increase in Residential Tariff Ceiling



Source: own composition

In Figure 22, an increase in electricity tariff for population from 11.98 to 14.38 UAH kop/kWh leads to drop in per capita electricity consumption from 36.23 to 35.06 kW per month.

Hence, the loss of residential consumer surplus would be equal to the area:

(8.7) $LCS_R = (K – J)\cdot Q_1 + ½\cdot(Q_0 – Q_1)\cdot(T_1 – T_0)$, or

(8.8) $LCS_R = 35.06\cdot(14.38 – 11.98) + ½\cdot(36.23 – 35.06)\cdot(14.38 – 11.98) =$

$= 84.14 + 1.40 = 85.54$ UAH kop. per capita (or 41,499.511 + 689.624 =

= 42,189.136 thsd UAH for Ukraine in total[1]).

[1] Here and further the per capita figures are transformed into the figures for Ukraine in total by multiplying them by Ukrainian population (the level of which: 49,319,632 is taken at the level of 2000:12. Source: http://upop.irex.ru/display_eco.asp)

41,499.511 of it will be transferred to the suppliers, whereas 689.624 represents the increase in the social loss in the household segment.

Assuming the suppliers' MC-curve to be, to a good approximation, linear at this short interval AF, one can approximate the change of suppliers' producer surplus because of the decrease in residential electricity demand.

According to NERC, in the last period, the costs of supplying 1 kWh were 13.82 UAH kop, 1.96 UAH kop of which was fixed cost. Therefore, the marginal costs can be approximated by variable costs of supplying 1 kWh: $MC \approx 13.82 - 1.96 = 11.86$ UAH kop (or 118.6 UAH/thsd kWh).

Hence, monthly losses of producer surplus from decrease in electricity consumption would be:

In the industrial electricity market:

(8.9) $LSS_I = (5{,}392{,}020 - 5{,}085{,}970) \cdot (143.5 - 118.6) = 7{,}620{,}646$ UAH (or 7,620.65 thsd UAH).

In the residential electricity market:

(8.10) $LSS_R = (36.23 - 35.06) \cdot (14.35 - 11.98) = 2.80$ UAH kop. per capita (or 1,379.249 thsd UAH for Ukraine in total).

Consequently, total monthly losses of producer surplus from decrease in electricity consumption would be:

(8.11) $LSS = LSS_I + LSS_R = 7{,}620{,}646 + 1{,}379{,}249 = 8{,}999{,}895$ UAH (or 8,999.9 thsd UAH).

Monthly gains of supplier surplus from increase in electricity tariffs would be:

In the industrial electricity market:

(8.12) $GSS_I = 5{,}085{,}970 \cdot (155.0 - 143.5) = 58{,}488{,}655$ UAH (or 58,488.66 thsd UAH), i.e. the amount extracted from industrial consumers' surplus.

In the residential electricity market:

(8.13) $GSS_R = 35.06 \cdot (14.38 - 11.98) = 84.14$ UAH kop. per capita (or 41,499.511 thsd UAH for Ukraine in total),

i.e. the amount extracted from residential consumers' surplus.

Consequently, total monthly gain in producer surplus from increase in electricity tariffs would be:

(8.14) $GSS = GSS_I + GSS_R = 58{,}488{,}655 + 41{,}499{,}511 = 99{,}988{,}166$ UAH

(or 99,988.166 thsd UAH), i.e. the total amount extracted from consumers surplus.

Finally, the net gain of electricity supplier from increase in tariffs would be:

(8.15) $NG = GSS - LSS = 99{,}988{,}166 - 8{,}999{,}895 = 90{,}988{,}271$ UAH

(or 90,988.271 thsd UAH).

So, the net gain of electricity suppliers would be positive and large.[1]

---

[1] All welfare changes resulting from the studied tariff increase are summarized in Appendix 15.

Social losses, which are the focus of this thesis, would, however, increase, too. The amount of this increase would consist of social losses (drained from consumer and producer surpluses) in industrial (1,759.79 and 7,620.65 thsd UAH respectively) and residential (689.624 and 1,379.249 thsd UAH respectively) markets, which were calculated above. The total monthly social losses would increase by:

(8.16) $SL = 1{,}759.79 + 7{,}620.65 + 689.624 + 1{,}379.249 = 11{,}449.313$ thsd UAH.

The latter figure in fact approximates the price, which Ukrainian society must pay for long run benefits from the improvement of situation in electricity industry due to 8% and 20% increase in electricity tariffs for industrial consumers and households respectively if the latter plans are implemented.

Chapter 9

CONCLUSIONS

Applying the conventional welfare analysis to Ukrainian electricity market yielded qualitative and quantitative answers to the central question of the thesis, i.e., the impact of the planned increase in electricity tariffs on welfare of the market players. To my knowledge, this is the first attempt to estimate elasticities of electricity demand by industries and households in Ukraine and to use them for evaluating the welfare results from the planned increase in electricity tariffs.

The increase, if allowed, is expected to harm electricity consumes and, on the *net*, benefit suppliers in both segments; however, some part of former surplus is likely to be just deadweight lost.

The increase in the social losses can be treated as the price, which Ukrainian society must pay for long run benefits from the improvement of situation in electricity industry due to the increase in electricity tariffs if the latter plans are implemented.

The implication of this conclusion for the further tariff policy is that this price should be weighted against the long-run social benefits mentioned while deciding about the new tariff policy implementation. Theoretically, the benefits must exceed the price, since planned changes in electricity market are consistent with transformation of Ukraine into a market economy. But the long-run benefits will not immediately arise to the full extent, while the extra social losses calculated above will. That is, in the *short* run, the social desirability of increase in electricity tariffs is (at least within a certain increases) not unambiguous. Therefore, while comparing the discussed costs and benefits, the government should apply some kind of '*weighting*' to them, or, equivalently, '*discount*' the benefits. The most probable result of such an approach is expected to be that the optimal solution will be to increase electricity tariffs *gradually*, with the speed not exceeding that of structural adjustments in other sectors and of population's accommodation.

Another argument for gradualism in increasing tariffs is that even the part of the loss in consumer surplus which is not deadweight (rather it is transferred to the supplier) may be socially harmful. As discussed in Ukrainian Context chapter, Ukraine inherited from the former USSR extremely energy-intensive economy, the efficiency of which is low for this reason. Though more energy-efficient plants must replace the current ones in the long run, this cannot occur quickly and simultaneously. Therefore, a shock caused by a suddenly large increase in electricity tariffs may destroy not just some, the most inefficient, enterprises, but large proportions of firms in several industries, thus resulting in a *system* crisis. If Ukrainian society is significantly concerned about such outcome, gradualism in further tariff policy can be warranted to the government.

The limitation on the results of my analysis is their short-run validity. With extension of the forecast period, precision of anticipations, naturally, decreases. It is reasonable for a policy-maker to follow Rhys' (1984) view on electricity demand forecasts, which treats specific numerical predictions as valid within some interval (that must contain the true value). Naturally, the width of the interval increases with prediction horizon.

One straightforward direction of further research would be to estimate of change in social welfare losses from increase in electricity tariffs by incorporating other sectors of the economy into the analysis.

Also, estimating the long-run elasticity of electricity demand and the corresponding welfare effects of tariff policies is a reasonable direction of the further research.

My thesis, then, can serve as a starting point for the subsequent sophisticated studies in the area traced above.

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APPENDICES

Appendix 1. The Descriptive Statistics for IT [Electricity Tariffs for Industries (UAH kop. per 1 kWh) from 1996 to 2000][1]

Categorized by values of IT
Sample: 1996:01 2000:12
Included observations: 60

IT	Mean	Median	Max	Min.	Std. Dev.	Obs.
[6, 8)	7.097357	6.975126	7.973784	6.716737	0.348930	29
[8, 10)	8.654834	8.575318	9.044569	8.344614	0.356688	3
[10, 12)	11.65027	11.58988	11.97549	11.32719	0.247605	7
[12, 14)	13.06514	13.07900	13.84135	12.10818	0.560724	21
All	9.795130	8.459966	13.84135	6.716737	2.834191	60

Appendix 2. The Descriptive Statistics for HT [Electricity Tariffs for Households (UAH kop. per 1 kWh) from 1996 to 2000]

Categorized by values of HT
Sample: 1996:01 2000:12
Included observations: 60

HT	Mean	Median	Max	Min.	Std. Dev.	Obs.
[0, 5)	4.190000	4.270000	4.990000	2.920000	0.646648	14
[5, 10)	7.229697	7.140000	9.890000	5.070000	1.623712	33
[10, 15)	10.86231	10.61000	12.98000	10.01000	0.849943	13
All	7.307500	7.115000	12.98000	2.920000	2.600556	60

[1] Data sources for the variables, the descriptive statistics for which are presented in the subsequent appendices, are: NERC, Derzhkomstat, UEPLAC, NBU. See also references in the main text.

Appendix 3. The Descriptive Statistics for RIT [Real Electricity Tariffs for Industries (UAH kop. per 1 kWh) from 1996 to 2000]

Categorized by values of RIT
Sample: 1996:01 2000:12
Included observations: 60

RIT	Mean	Median	Max	Min.	Std. Dev.	Obs.
[1.6, 1.8)	1.751715	1.768413	1.795978	1.659989	0.041052	18
[1.8, 2)	1.897331	1.888356	1.992312	1.800655	0.057899	35
[2, 2.2)	2.090279	2.069680	2.170319	2.012774	0.067233	5
[2.2, 2.4)	2.242723	2.242723	2.279181	2.206264	0.051560	2
All	1.881238	1.861747	2.279181	1.659989	0.127175	60

Appendix 4. The Descriptive Statistics for RHT [Real Electricity Tariffs for Households (per 1 kWh) from 1996 to 2000]

Categorized by values of RHT
Sample: 1996:01 2000:12
Included observations: 60

RHT	Mean	Median	Max	Min.	Std. Dev.	Obs.
[2, 3)	2.920000	2.920000	2.920000	2.920000	NA	1
[3, 4)	3.629611	3.654395	3.958246	3.133913	0.259755	17
[4, 5)	4.460255	4.498356	4.962227	4.015135	0.298491	31
[5, 6)	5.369429	5.407250	5.644520	5.052886	0.179085	11
All	4.365917	4.347475	5.644520	2.920000	0.673136	60

Appendix 5. The Descriptive Statistics for Q [Physical (bln. kW) Amounts of Electricity Consumed in the Industrial Segment from 1996 to 2000]

Categorized by values of Q
Sample: 1996:01 2000:12
Included observations: 60

Q	Mean	Median	Max	Min.	Std. Dev.	Obs.
[1000000, 2000000)	1855075.	1855075.	1855075.	1855075.	NA	1
[2000000, 3000000)	2713420.	2799950.	2917255.	2311833.	247428.5	5
[3000000, 4000000)	3455986.	3469425.	3866726.	3029638.	319002.9	13
[4000000, 5000000)	4508544.	4507414.	4981537.	4039607.	268843.1	21
[5000000, 6000000)	5557031.	5595084.	5985168.	5109473.	301810.5	17
[6000000, 7000000)	6157721.	6188767.	6251668.	6032729.	112722.9	3
All	4466202.	4535872.	6251668.	1855075.	1079001.	60

Appendix 6. The Descriptive Statistics for Y [Physical (bln. kW) Amounts of Electricity Consumed in the Residential Segment from 1996 to 2000]

Categorized by values of Y
Sample: 1996:01 2000:12
Included observations: 60

Y	Mean	Median	Max	Min.	Std. Dev.	Obs.
[20, 30)	27.44825	27.45282	29.59618	24.35182	1.690753	20
[30, 40)	34.76988	35.19762	39.27218	30.10362	2.764093	31
[40, 50)	44.16217	43.62817	49.45418	40.58688	2.755320	9
All	33.73818	33.12238	49.45418	24.35182	6.031629	60

Appendix 7. The Descriptive Statistics for IRIP [the Index of Real Industrial Production from 1996 to 2000*]

Categorized by values of IRIP
Sample: 1996:01 2000:12
Included observations: 60

IRIP	Mean	Median	Max	Min.	Std. Dev.	Obs.
[22, 24)	23.80000	23.80000	23.80000	23.80000	NA	1
[24, 26)	25.38385	25.30000	25.90000	24.60000	0.379156	13
[26, 28)	26.75125	26.74500	27.90000	26.00000	0.484760	32
[28, 30)	29.18250	29.26500	29.80000	28.50000	0.402134	12
[30, 32)	30.30000	30.30000	30.50000	30.10000	0.282843	2
All	27.01033	26.74500	30.50000	23.80000	1.518124	60

* Base year: 1990 = 100

Appendix 8. The Descriptive Statistics for X [Household Monthly Money Expenditures (UAH mln per capita) from 1996 to 2000]

Categorized by values of X
Sample: 1996:01 2000:12
Included observations: 60

X	Mean	Median	Max	Min.	Std. Dev.	Obs.
[50, 100)	77.96872	79.15200	98.23216	50.27847	13.16574	41
[100, 150)	118.5292	112.6842	142.2465	103.8429	13.22554	14
[150, 200)	163.4236	159.7452	171.2355	159.2890	5.557736	5
All	94.55408	87.34217	171.2355	50.27847	29.79346	60

Appendix 9. The Descriptive Statistics for Possession of Electricity-using Equipment Per 1000 Population (items, adjusted to beginning of month) from 1996 to 2000

Descriptive Statistics for FR [Freezers and Refrigerators]
Categorized by values of FR
Sample: 1996:01 2000:12
Included observations: 60

FR	Mean	Median	Max	Min.	Std. Dev.	Obs.
[120, 140)	136.5663	136.5886	139.7401	133.3365	2.395552	6
[140, 160)	150.4867	150.5321	159.8387	140.9756	5.940095	17
[160, 180)	170.3286	170.3210	179.6797	161.0000	5.897455	17
[180, 200)	190.1558	190.1603	199.4574	180.8484	5.867770	17
[200, 220)	201.8146	201.8120	203.0000	200.6316	1.184186	3
All	168.5225	168.5689	203.0000	133.3365	20.45959	60

Descriptive Statistics for TV
Categorized by values of TV
Sample: 1996:01 2000:12
Included observations: 60

TV	Mean	Median	Max	Min.	Std. Dev.	Obs.
[100, 150)	129.1423	129.9246	149.4613	106.1755	13.52629	18
[150, 200)	175.9292	176.1174	199.5205	151.5971	14.68145	25
[200, 250)	217.0417	216.6752	234.0000	201.4224	10.15315	17
All	173.5417	175.1195	234.0000	106.1755	36.29609	60

Descriptive Statistics for VC [Vacuum Cleaners]
Categorized by values of VC
Sample: 1996:01 2000:12
Included observations: 60

VC	Mean	Median	Max	Min.	Std. Dev.	Obs.
[60, 80)	74.90357	75.02464	79.17914	70.28947	3.041176	9
[80, 100)	89.92182	89.99005	99.40781	80.14367	5.843358	24
[100, 120)	109.7887	109.7154	119.5437	100.2638	5.995622	22
[120, 140)	122.2406	122.2528	124.0000	120.4566	1.400896	5
All	97.64683	97.30256	124.0000	70.28947	15.39160	60

Appendix 10. The Estimation Output for Electricity Demand in the Industrial Segment

Estimation Command:
=====================
LS Q_LN C IRIP_LN RIT_LN AR(1)

Estimation Equation:
=====================
Q_LN = C(1) + C(2)*IRIP_LN + C(3)*RIT_LN + [AR(1)=C(4)]

Substituted Coefficients:
=====================
Q_LN = 16.317 + 0.011*IRIP_LN - 0.710*RIT_LN + [AR(1)=0.813]

Dependent Variable: Q_LN [Log of Electricity Consumption by Industries]
Method: Least Squares
Sample(adjusted): 1996:02 2000:12
Included observations: 59 after adjusting endpoints
Convergence achieved after 5 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	16.31718	0.862069	18.92793	0.0000
IRIP_LN	0.010569	0.014022	0.753768	0.4542
RIT_LN	-0.709498	0.367743	-1.929329	0.0589
AR(1)	0.813208	0.077266	10.52472	0.0000

R-squared	0.726881	Mean dependent var	15.27407
Adjusted R-squared	0.711984	S.D. dependent var	0.266390
S.E. of regression	0.142964	Akaike info criterion	-3.824940
Sum squared resid	1.124124	Schwarz criterion	-3.684090
Log likelihood	33.11837	F-statistic	48.79258
Durbin-Watson stat	1.892073	Prob(F-statistic)	0.000000

Appendix 11. The Estimation Output for Electricity Demand by Residential Holdings

Estimation Command:
=====================
LS Y C RHT(-1) FR_DT PEAK OFF-PEAK Y(-1) Y(-12) Y(-13)

Estimation Equation:
=====================
Y = C(1) + C(2)*RHT(-1) + C(3)*FR_DT + C(4)*PEAK + C(5)*OFF-PEAK + C(6)*Y(-1) + C(7)*Y(-12) + C(8)*Y(-13)

Substituted Coefficients:
=====================
Y = 20.435 - 1.296*RHT(-1) + 3.307*FR_DT + 2.869*PEAK - 2.659*OFF-PEAK + 0.336*Y(-1) + 0.678*Y(-12) - 0.451*Y(-13)

Dependent Variable: Y [Electricity Consumption by Residential Holdings]
Method: Least Squares
Sample(adjusted): 1997:02 2000:12
Included observations: 47 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	20.43536	6.927200	2.950017	0.0053
RHT(-1)	-1.295627	0.712260	-1.819036	0.0766
FR_DT	3.307190	2.066470	1.600406	0.1176
PEAK	2.869276	1.293674	2.217928	0.0325
OFF-PEAK	-2.658600	1.015552	-2.617887	0.0125
Y(-1)	0.335482	0.142828	2.348842	0.0240
Y(-12)	0.677888	0.105092	6.450447	0.0000
Y(-13)	-0.451155	0.122721	-3.676256	0.0007

R-squared	0.895328	Mean dependent var	32.79995
Adjusted R-squared	0.876540	S.D. dependent var	5.605602
S.E. of regression	1.969629	Akaike info criterion	4.347407
Sum squared resid	151.2982	Schwarz criterion	4.662326
Log likelihood	-94.16407	F-statistic	47.65597
Durbin-Watson stat	2.001154	Prob(F-statistic)	0.000000

Appendix 12. Estimated Residential Electricity Demand Elasticities for 1996-2000.

Year	Month	Real El. Tariff. UAH kop/kWh	Households' El. Consumption per Capita*, kW	Price Elasticity of Residential Electricity Demand
1996	1	2.92	49.45	-0.076
1996	2	3.18	43.63	-0.094
1996	3	3.17	42.56	-0.096
1996	4	3.13	33.53	-0.121
1996	5	3.4	30.1	-0.146
1996	6	3.62	29.59	-0.158
1996	7	3.61	32.67	-0.143
1996	8	3.65	31.4	-0.150
1996	9	3.77	31.56	-0.155
1996	10	3.72	35.32	-0.136
1996	11	3.82	36.12	-0.137
1996	12	4.06	44.11	-0.119
1997	1	3.65	42.66	-0.111
1997	2	3.84	36.9	-0.135
1997	3	3.64	37.27	-0.126
1997	4	3.74	33.31	-0.145
1997	5	4.02	29.49	-0.176
1997	6	4.13	28.43	-0.188
1997	7	4.25	29.17	-0.188
1997	8	4.31	27	-0.206
1997	9	4.02	30.78	-0.169
1997	10	4.08	35.94	-0.147
1997	11	3.96	36.43	-0.141
1997	12	4.81	46.41	-0.134
1998	1	3.94	39.16	-0.130
1998	2	4.06	34.14	-0.154
1998	3	3.84	37.83	-0.131
1998	4	4.2	32.57	-0.167
1998	5	4.69	30.72	-0.197

1998	6	4.93	25.16	-0.253
1998	7	5.38	27.15	-0.256
1998	8	5.41	25.84	-0.271
1998	9	5.64	28.98	-0.252
1998	10	4.77	35.2	-0.175
1998	11	4.82	39.27	-0.159
1998	12	4.6	46.23	-0.129
1999	1	4.14	38.46	-0.139
1999	2	4.17	36.28	-0.149
1999	3	4.45	40.59	-0.142
1999	4	4.96	30.85	-0.208
1999	5	5.13	28.27	-0.235
1999	6	5.57	25.12	-0.287
1999	7	5.45	27.49	-0.257
1999	8	5.46	28.07	-0.252
1999	9	5.25	29.6	-0.229
1999	10	5.05	35.22	-0.186
1999	11	4.91	37.03	-0.171
1999	12	5.27	41.82	-0.163
2000	1	4.6	38.61	-0.154
2000	2	4.53	33.44	-0.175
2000	3	4.58	32.2	-0.184
2000	4	4.58	25.55	-0.232
2000	5	4.54	26.13	-0.225
2000	6	4.5	24.35	-0.239
2000	7	4.35	26.61	-0.212
2000	8	5.44	27.41	-0.257
2000	9	4.92	29.56	-0.215
2000	10	4.45	32.94	-0.175
2000	11	4.34	34.56	-0.163
2000	12	4.52	38.08	-0.154
2001	1	4.10247	35.56	-0.149
2001	2	4.2289	35.07	-0.156
2001	3	4.0383	35.35	-0.148
2001	4	4.28175	28.68	-0.193

2001	5	4.2496	25.28	-0.217
2001	6	4.27302	23.75	-0.233
2001	7	4.28968	26.08	-0.213
2001	8	4.54684	24.25	-0.242
2001	9	4.75344	28.55	-0.215
2001	10	4.48547	33.18	-0.175
2001	11	4.53124	36.23	-0.162

* After 2000:12, population assumed constant at the level of 2000:12.

Appendix 13. Residuals Correlogram and Tests for Autocorrelation and Heteroscedasticity in the Regression for Industrial Electricity Demand.

Sample: 1996:02 2000:12
Included observations: 59
Q-statistic probabilities adjusted for 1 ARMA term(s)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.045	0.045	0.1245	
		2	-0.039	-0.041	0.2197	0.639
		3	0.011	0.014	0.2271	0.893
		4	-0.004	-0.007	0.2282	0.973
		5	0.004	0.005	0.2291	0.994
		6	-0.117	-0.119	1.1606	0.949
		7	-0.051	-0.040	1.3420	0.969
		8	0.010	0.005	1.3493	0.987
		9	0.001	0.000	1.3493	0.995
		10	0.037	0.038	1.4505	0.997
		11	0.044	0.043	1.5985	0.999
		12	-0.134	-0.151	2.9672	0.991
		13	0.082	0.091	3.4992	0.991
		14	-0.036	-0.060	3.6020	0.995
		15	-0.080	-0.066	4.1292	0.995
		16	-0.098	-0.094	4.9360	0.993
		17	-0.167	-0.155	7.3348	0.966
		18	-0.124	-0.164	8.6932	0.949
		19	-0.057	-0.062	8.9899	0.960
		20	0.077	0.067	9.5415	0.963
		21	0.116	0.091	10.827	0.951
		22	0.050	0.040	11.073	0.961
		23	0.090	0.073	11.885	0.960
		24	0.122	0.061	13.419	0.942

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.102255	Probability	0.902977
Obs*R-squared	0.226787	Probability	0.892799

White Heteroskedasticity Test:

F-statistic	1.098758	Probability	0.372133
Obs*R-squared	5.541333	Probability	0.353435

Augmented Dickey-Fuller Unit Root Test

ADF Test Statistic	-7.149907	1% Critical Value*	-2.6026
		5% Critical Value	-1.9462
		10% Critical Value	-1.6187

Appendix 14. Residuals Correlogram and Tests for Autocorrelation and Heteroscedasticity in the Regression for Residential Electricity Demand.

Sample: 1997:02 2000:12
Included observations: 47

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.003	-0.003	0.0004	0.984
		2	-0.137	-0.137	0.9666	0.617
		3	0.163	0.166	2.3654	0.500
		4	-0.071	-0.097	2.6345	0.621
		5	0.069	0.125	2.8935	0.716
		6	-0.045	-0.113	3.0095	0.808
		7	-0.005	0.068	3.0110	0.884
		8	0.023	-0.053	3.0434	0.932
		9	-0.149	-0.100	4.3953	0.884
		10	0.046	0.026	4.5274	0.920
		11	0.108	0.089	5.2792	0.917
		12	0.047	0.097	5.4218	0.942
		13	-0.229	-0.272	8.9798	0.774
		14	-0.070	-0.017	9.3172	0.810
		15	0.118	0.009	10.320	0.799
		16	-0.365	-0.344	20.203	0.211
		17	-0.116	-0.107	21.233	0.216
		18	0.022	-0.101	21.273	0.266
		19	-0.111	-0.016	22.279	0.271
		20	0.149	0.137	24.183	0.234

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.612875	Probability	0.547199
Obs*R-squared	1.507107	Probability	0.470691

White Heteroskedasticity Test:

F-statistic	0.644706	Probability	0.851158
Obs*R-squared	27.99946	Probability	0.669387

Augmented Dickey-Fuller Unit Root Test

ADF Test Statistic	-6.717134	1% Critical Value*	-2.6132
		5% Critical Value	-1.9480
		10% Critical Value	-1.6195

Appendix 15. Summary of Anticipated Welfare Changes Resulting From the Increase in Electricity Tariffs

Value, thsd. UAH / Segment	CS-loss			Seller Surplus		Total ↑ in Social Loss
	Total	Transfer to Producer Surplus	Dead-weight Loss	Dead-weight Loss	Net Gain	
Industrial	60,248.44	58,488.65	1,759.79	7,620.65	58,488.65	9,380.43
Households	42,189.14	41,499.51	689.62	1,379.25	41,499.51	2,068.87
Total	102,437.58	99,988.16	2,449.41	8,999.90	90,988.27	**11,449.31**