Explaining Factors Affecting Energy Demand Elasticity: Does the Quality of Institutions Matter?

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1. Introduction

In many countries, during the last decades of the previous century, especially following the energy crisis of 1970s, there was a pronounced declining trend in energy intensity of production. Thus, in the OECD countries (without new members) the average energy intensity reduction from 1973 to 2000 exceeded 15%. For such countries as Denmark, Germany, United Kingdom, USA, and Ireland the decrease was about 40%. At the same time, in transition countries energy consumption per unit of production stays essentially higher and exceeds several fold the levels of the West European countries and Japan. In our opinion, this circumstance could hinder further economic growth of these countries.

For instance, RF energy intensity of production is higher than in Canada by 1/3, it is two times greater than in USA, Sweden and Finland, and exceeds the level of most countries of Western Europe and Japan - 3-4 times. The 3-fold production growth targeted by the Russian Government document "Energy Strategy of Russia for the period up to 2020"[1] is impossible without a drastic increase in the energy consumption efficiency. Such an increase was proposed by one of the "Strategy" sections, however, such rates are hardly attainable. Thus, it was projected that in 20 years energy use per unit of GDP would reduce more than by half and in addition, after 2010 the annual reduction rate of energy intensity reduction will exceed 5%. Such a task seems to be unprecedented on a historical scale. Thus, it is quite urgent to identify the main sources and means of energy conservation feasible for the transitional countries including Russia.

This paper explains factors defining higher energy intensity of production in the former socialist countries as compared to the market economies. We confirm that more severe climatic conditions in most of the post-socialist countries can partially account for this. However, we believe that the “socialist hangover” may also be largely responsible for higher energy intensity in these counties. Namely, we show that in the economies with strong economic institutions, economic agents have higher incentives to implement energy conservation measures than in the countries with weaker institutional environment. For this purpose, we, first, specify transaction cost of a firm as a total cost of an economic agent on interaction with all his partners (Polterovich, 1999a). In such a view it includes some explicit fraction which could be easily taken into account when calculating the total project cost, and a certain implicit fraction being a sum of both monetary but unofficial transaction cost (e.g. bribes) and non-monetary component, such as “efforts”. By our proposition if economic institutions are bad and by this reason the markets are ineffective the total transaction cost could be high especially due to its implicit fraction. Further we propose a theoretical model of a representative economic sector including a certain number of energy consuming firms, which are included in an energy conservation project under the condition of uncertain

[1] Passed by the RF Government directive No1234p, August, 28, 2003

transaction associated with implementation of this project. Each firm can face both a high transaction cost (because implicit fraction of transaction cost is large), and a low transaction cost (when it is low). A high transaction cost completely stops the project because the firm perceives it difficult to realize the project, i.e. the total cost on its implementation is too high. But low transaction cost does not affect the behavior of the firms. We show that the inadequate institutional environment resulting in a high probability for a firm to be faced with adverse external conditions resulting in the high transaction cost brings about the lack of incentives. Thus, under such a condition the substitution effect of energy price change is weaker than in a tough market environment.

Further we present a macroeconomic econometric model, which along with the climate and real energy price variables includes an interaction term being a product of a price variable multiplied by an index of institutional strength. This model makes it possible to calculate energy price elasticity of energy intensity of production being a value similar to price elasticity of conditional demand for energy. We tested various versions of interaction terms using different institutional indices and found out the key role of the conditions defining relations between business and bureaucracy: two institutional variables from their common list provided in (Kaufmann, Kraay and Zoido-Lobatón, 1999) are of high significance. We present coefficients of energy price elasticity of energy intensity of production both by groups of the countries and for each economy from the sample. We show that the average of these coefficients for the CIS group is more than four times lower than that for the OECD economies (by their absolute values); in the East European and Baltic countries these values are also visibly lower than in the developed countries although the difference is not so drastic ("only" two times). This fact implies that firms do not have sufficient incentives for energy conservation and, thus, may be an important factor of the higher energy intensity of production.

Analysis is based on 2000 statistical data involving a large country sample, which along with 25 former socialist economies includes the OECD countries and also some states from Asia, Africa and America. A variable of unofficial economy added to regressions helps to improve the estimate reliability. We apply both OLS and IVLS estimators, institutional variables being instrumented by the infant mortality rate. The import oil cost per unit of oil is used to instrument energy price variables.

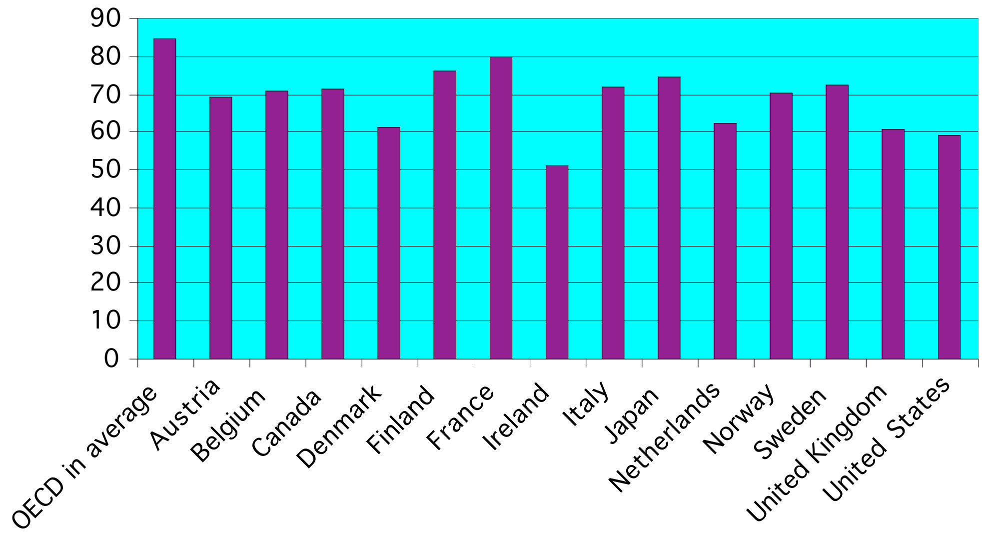
The paper is organized in a following way. In section 2, we present a brief discussion of the energy consumption trends during the last decades of the previous century by separate groups of world economies. In section 3, a review of literature on the discussed topic is presented. Section 4 is devoted to the consideration of statistical sources, a theoretical model and specifications estimated. Section 5 considers results of energy intensity estimations of integrated models including interaction terms being calculated using various institutional variables. An influence of unofficial economy on the levels of specific energy consumption is estimated and discussed as well. The conclusion is presented in Section 6.

2. Energy Intensity Puzzle

Before the energy crisis of 1970s, the main trends in energy consumption especially evident in the countries with average income were increased per capita energy consumption and growing energy intensity. Thus, we observe that the average per capita consumption of commercially produced energy had practically doubled in today's OECD countries from 1960s to 1973, out of which in Japan, Portugal, and Spain this growth was 2.5-3 times, and in Greece the increase was almost 5 times. Accordingly, the energy intensity of the income produced grew too. The average growth index of energy intensity for OECD countries over this period was 120%.

During the decade following the energy crisis break-up, the energy consumption trends were reversed in most countries. By 1983, the average reduction index of GDP energy intensity for OECD countries was 10%, and by the end of the century this index dropped by further 4%. At the same time, however, in such OECD member countries as Australia, Belgium, Denmark, Italy, Japan, Great Britain, and USA, the reduction in the GDP energy intensity exceeded 20% over the first post-crisis decade and 30-40% - before the end of the century (see Fig. 1). Obviously, such a striking improvement of the energy consumption efficiency in the above-mentioned countries should be attributed not only to the skyrocketing energy prices in the efficient markets but also to the special measures of government policy aimed at better energy conservation.

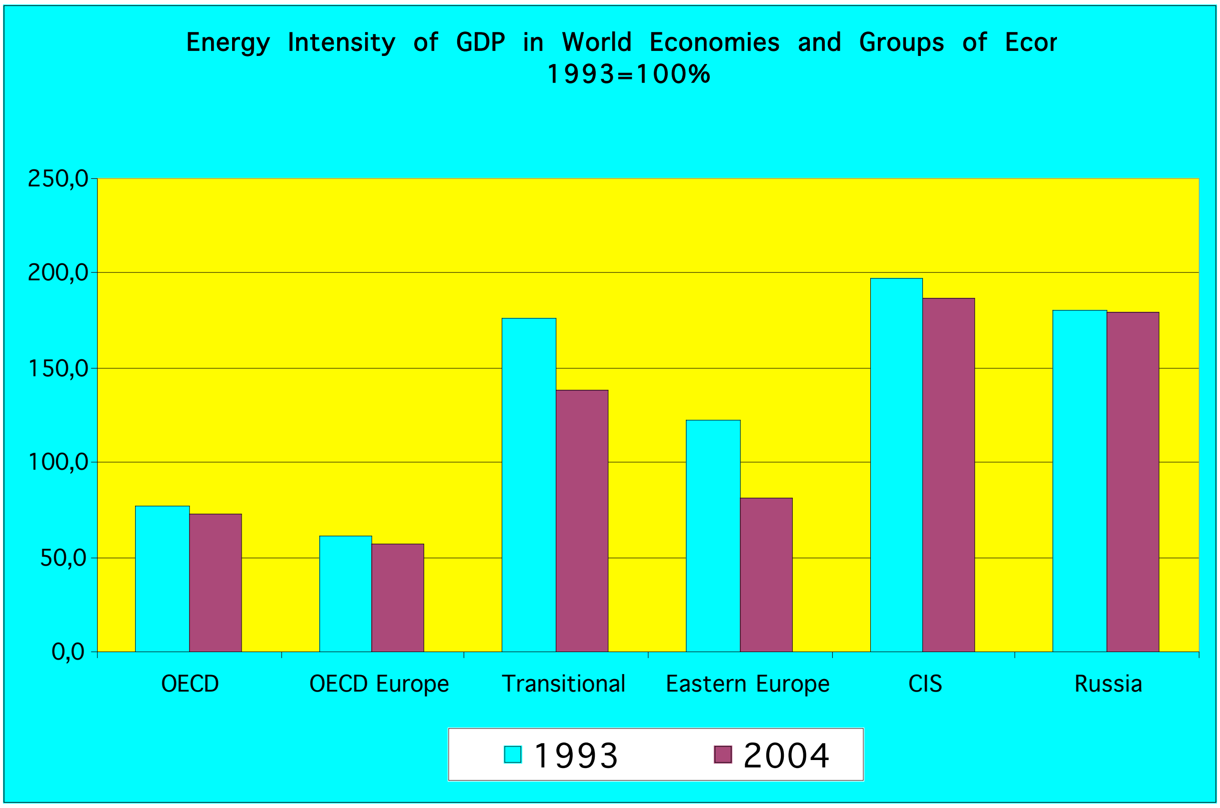
Figure 1. Change in the GDP Energy Intensity in Selected O
Economies: 2000 to 1973, %



The available data for the countries with socialist economy show that there too was a certain reduction in the output energy intensity in 1970s and 1980s, although is already universally recognized that the official statistics in socialist countries overestimated the output growth indices, and, consequently, the data on the energy intensity dynamics lack reliability. In the early 1990s when the economic reforms were launched, the GDP energy intensity in transitional economies significantly – as often as not several fold – exceeded the levels of market economies, and the situation has not changed significantly since that time (see Fig. 2). The initial transformation period in former socialist countries was characterized by increasing energy intensity of production resulting from the shrinking output. After this, however, in most of the above-mentioned countries energy intensity of production decreased fairly fast, although not everywhere it approached the pre-crisis levels. As was shown in (Suslov and Ageeva, 2005), the reduction in the energy intensity of production over the above-named period was little related to the increase in the energy prices, and was rather a “byproduct” of increase in the production and capacity utilization.

Higher energy inputs in former socialist countries may partially be attributed to the inclement climatic conditions: in this part of the East Europe and the Asian part of the former Soviet Union average annual temperatures are significantly lower and the amplitude of seasonal variations is much higher than in, say, Western Europe. However, as our analysis showed (Suslov and Ageeva, 2005), this factor fails to account for the entire difference in the levels of energy intensity. This suggests that a significant factor affecting the levels of specific energy consumption is the quality of economic institutions determining the key aspects of economic system performance mechanism. Our hypothesis is that weak institutional development can lower the incentives for economic agent to take energy conservation measures, including the implementation of investment projects aimed at energy saving.

In the later sections, a theoretical model is discussed and tested intended to explain why the increasing energy prices sometimes fail to result in replacement of energy by other factors. We suppose that the weak institutional framework results in unfavorable conditions for investment activity. Not only such systems are exposed to additional risks, which in itself can undermine the attractiveness of investment projects, but the inefficient markets functioning can increase the costs of their implementation. The banking system drawbacks, immature and often practically non-existent stock markets hinder and often preclude financing of large-scale and long-term projects. Under such conditions it can only be expected that the equipment used will be comparatively more obsolescent than in the countries with efficient institutions, which might be the cause of higher energy costs. Moreover, there may also be insufficient incentives for implementing energy-saving investment projects even when energy prices increase significantly.



3. Review of Literature

The well-known approach to treat the relationship between output, energy consumption, and other production factors is based on application of translog cost function (Hudson and Jorgensen, 1974; Berndt and Wood, 1975, Griffin and Gregory, 1976). It permits, for example, to make long-term estimates of demand for energy price elasticity coefficients. Although this methodology has significant advantages, it is hardly suitable cannot properly allow for singularities of the objects considered. In any case, to take them into account a panel data model should be applied (Griffin and Gregory, 1976), but in this case it will be difficult to include in the samples both transitional economies and many other non-OECD countries, which still lack the factor price series statistics. Moreover, the translog cost function approach does not allow one reliably to test the significance of separate factors responsible for individual countries differences and at best can only show their aggregate impact on the energy intensity of production.
For these reasons, we chose a simpler approach, with less stringent requirements to statistics. We consider an economy a system with a complex structure consisting of separate sectors. In this aspect, our methodology dates back to the Chenery hypothesis, which suggests that growth rates of economic sectors are correlated with per capita income level (Chenery, 1960, Chenery and Taylor, 1968). Many authors used this framework to analyze production structure distortions in socialist and transitional economies (Winiecki, 1988; Doern and Heilemann, 1996; Jackman and Pauna, 1995). Raiser, Shaffer and Schuchhart (Raiser, Schaffer and Schuchhart, 2003) developed a model, linking distortions of the production structure with insufficient demand for services and the respectively low labor productivity. Thus they proved that the above-mentioned distortions are stable and natural for such countries.

During the recent period, the problem of influence of the institutional strength on the economic outcomes attracted special attention of researchers (Rodrik, 1997; Tanzi and Davoodi, 1997; Wei, 1997, Johnson, Kaufman and Zodio-Lobaton, 1998, Hall and Jones, 1999; Chong and Calderon, 1999, Kaufman, Kraay and Zodio-Lobaton, 1999; McArthur and Sachs, 2001; Rodrik, Subramanian and Trebbi, 2002). It is proved that there is a strong correlation between the quality of institutions and policies on the one hand, and the per capita income level on the other hand. For transitional economies, variations in the duration of transformation decline period are determined by counties' ability to maintain efficient government institutions and to develop market institutional framework (Sachs, 1999; Aslund, Boone. and Jonson, 1996; Krueger and Ciolko, 1998; Popov, 1998; Transition Reports, 1999, 2001). In addition, the strength of the transformation decline is associated with the distortions in the fixed capital, production and the trade patterns "accumulated" before the reforms launch (De Melo, Denizer, Gelb and Tenev, 1997; Krueger and Ciolko, 1998; Popov, 1999). The overriding importance of institutional transformation for bringing countries out of the economic recessions and further developments in the transitional countries demonstrated an urgent need for a special scientific discipline to work out an effective strategy and methods for the market transformation (Polterovich, 1999b, 2001). Fredriksson, Vollebergh, and Dijkgraaf (2004) provided a theoretical model of corruption influence on energy efficiency. They found a strong correlation between the corruption variable and energy intensity of production sectors in the OECD economies over the period from 1982 to 1996.
The analysis of correlation between institutional and biogeographical conditions revealed the significance of the latter; therefore some medical and biogeographical determinants may also be used as instrumental variables for the institutional strength indices (for review see Olsson, 2003). An example of such variables is the country's geographical distance from the equator suggested by Hall and Jones (1999). In our work population death rate is used as one of the instrumental variables measuring the capacity of regulatory institutions (following Acemoglu, Johnson and Robinson, (2000)).
The distinctive feature of our work is analyzing the influence of climatic conditions on economic outcomes. Here we could refer to the recent publications by Jeffry Sachs (Bloom and Sachs, 1998; Sachs, 2001) who investigated the effects of the mean temperature and some other biogeographical factors on the agricultural production in developing countries.
The well-known approach to measure the scale of unofficial economy in transitional countries is using electricity consumption methodology (Gavrilenkov & Koen, 1994; Kuboniwa, 1995; Kaufmann and Kaliberda, 1996; Johnson et. al., 1997, 1998; Schneider and Enste, 2000; Lacko, 2000, Alexeev and Pyle, 2003). This method proceeds from the suggestion that electricity consumption is better documented by official statistics, electricity factor elasticity of output being fairly constant. In this case energy intensity as calculated using official statistics should be the higher, the larger the share of unofficial sector is. Recent publications, emphasize the overriding role of corruption in the development of shadow economy, especially in the developing and transitional economies (Ernste, Schneider, 1998; Johnson, Kaufmann and Zoido-Lobatón, 1998, Friedman, Johnson, Kaufmann, Zoido-Labton, 2000; Schneider and Enste, 2000; Dreher et. al., 2005; Dreher and Schneider, 2006). The idea of the complementarity of corruption and the shadow economy was also suggested (see also Cule and

Fulton, 2005). Stricter regulations increase both corruption and the shadow economy; at the same time the shadow economy reduces corruption in high-income countries, but increases corruption in low-income countries (Dreher and Schneider, 2006).
In our regressions, we use estimates of the shadow size in different countries provided in some publications (Friedman, Johnson, Kaufmann, and P. Zoido-Lobatón, 2000; Alexeev and Pyle, 2003).

4. Methodology of Research

4.1 Data and Variables

We use several samples with sizes determined by the requirement for data homogeneity and by variations in the number of countries, for which a specific type of data is available. Thus, we use a sample including market economies, a sample including transition economies and the sample including all of them. Availability of the price employment and unofficial economy size statistics narrows the number of the countries involved in the research. Since we are interested in just the long run differences between the economies we employ the cross country analysis rather than the one based on time series. Thus, in order to provide the comparability of indicators treated by countries we use PPP income variable rather than a real one. Analysis of energy intensity time change indices based on the use of real variables was fulfilled as well and showed the results which are qualitatively similar to those discussed in the present paper but quantitatively less conclusive as compared to them (Suslov, Ageeva, 2005). Whereas we focus our analysis on the use of energy as a production factor, we restrict the subject of investigation with only the production sphere and remove the consumption of energy by households from our consideration. Thus, we deal with energy intensity of production and consider the models of firms. The total sample refers to the year of 2000 and includes 74 economies and among them - 25 former socialist ones, 25 OECD countries (without new members) and some other economies from Asia, Africa and America as well. The series for unofficial economy consists of only 55 observations and concerns the middle of 1990ths (Friedman, Johnson, Kaufmann, Zoido-Lobaton, 2000; Alexeev and Pyle, 2003).

We use the following information[2]:
Y - GDP in PPP.
E - energy consumption in production sphere**.** This variable is calculated as the total energy supply in the country less the consumption of households and non-energy use.
e - energy intensity of production calculated as ***E /Y.***
DISTE - seasonal temperature fluctuation is used calculated as the difference between mean temperature values in January and July for the period of 1961-1990, measured in tenths of degree centigrade - data from Intergovernmental Panel on Climate Change (IPCC).
INST - institutional strength indices obtained from Research project "Governance Matters III: Governance Indicators for 1996-2002". The following variables are

[2] A complete least of variables and statistical sources to prepare them is presented in Appendix 1 in Table A1.

used directly in regressions for the year of 2000 (Kaufmann, Kraay and Zoido-Lobatón, 1999):
VOACC (Voice and Accountability) - measures the extent, to which citizens of a country are able to participate in the election of governments.
POIST (Political Instability and Violence) - measures perceptions of the likelihood that the government in power will be destabilized or overthrown by unconstitutional means.
GOEFF (Government Effectiveness) - measures quality of bureaucracy and credibility of the government's commitment.
REGBU (Regulatory Burden) - measures the incidence of market unfriendly policies including price controls and inadequate bank supervision.
RULAW (Rule of Law) - measures the extent, to which agents have confidence in and abide by the rules of society.
GRAFT (Graft) - measures perceptions of corruption.
All these indices are averages for the period of 1996-2000.
SHUN95 **-** share of unofficial economy in GDP in the middle of 1990ths. The main source of the data for this variable ***s*** is the sample provided in (Friedman, Johnson, Kaufmann, Zoido-Lobaton, 2000) developed with the help of MIMIC approach. From the two series provided in this source (Friedman et. al., 2000, Table 1, pp. 266-268) the second one designated as SHARE2 and obtained with more intensive use of the demand for electricity methodology demonstrated a higher significance in our regressions. In addition, we introduce into this sample alternative indices for 11 CIS countries calculated using earlier estimates for corresponding former Soviet republics and dynamic indices of electricity consumption (Alexeev and Pyle, 2003). The series constructed proved itself to have still higher significance in our regressions, so, we considered it as the most appropriate measure for the size of shadow economy.
p_E - end use energy price for industry. It was calculated using statistical data from two sources: 1) IEA database – end-use prices for industry for different energy products for 2000 and for the year of 2001 for Latin America economies; 2) Transition Report, EBRD, 2001 - electricity tariffs for industry for the transitional countries for the year of 2000. For each energy product a partial price index was calculated as compared to the USA level. Since the above-mentioned databases are not complete, we obtained different numbers of such indices (from 1 to 6) for different countries. Further for each economy aggregate, a price energy index was computed as a geometrical mean of all the partial indices. For 2000, we supplemented the total sample by 20 economies from Latin America. The prices for them were taken from IEA database, for which only the data after 2001 were available. Each energy product price was adjusted using its annual 2001 price index. The latter was obtained as the geometrical mean of such indices for all the countries. The indices obtained we considered as estimate of the true energy prices in these countries and used in the regressions.
P - average output price calculated as a relation of nominal GDP in US$ to PPP GDP.
The following variables are used as the instrumental ones: oil import cost per unit of oil (IEA data), citizens' death rate and infant mortality rate (data from World Development Indicators 2002 CD-ROM).
Some additional variables used are introduced further in the respective sections of the paper.

4.2 Theoretical Model.

As a theoretical framework to construct a specific macroeconomic demand for energy function for each economy considered we assume a simple multi-sector economic system. For each economy considered ***m*** economic sectors are given designated by index ***i***. Their technologies

$$Q_i=F_i(E_i,\ldots),\ i=1,\ldots m \tag{1}$$

are characteristic of the representative firms in the sector are described by CES production functions. In (1) Q_i is the output of the sector i, E_i is the energy consumption in this sector. The existence of other production factors is designated by suspension points (…). We assume that sector production functions in all the economies have equal partial elasticities of substitution, though can differ by some other parameters (see below).

Given the equilibrium on competitive markets sector i the demand for energy E_i is obtained:

$$E_i = [\alpha_i \cdot A_i^{-\rho i} \cdot (P_i/p_E)]^{\sigma i} \cdot Q_i, \tag{2}$$

where α_i- is the energy factor intensity coefficient, p_E and P_i are energy and output prices respectively, σ_i –stands for the partial elasticity of substitution between energy and another factor, ρ_i – is the parameter such that $1/(1+\rho_i)=\sigma_i$, and A_i –stands for the efficiency coefficient. Now the energy intensity of the economies as follows:

$$e = \sum s_i \cdot [\alpha_i\, A_i^{-\rho i} \cdot (P/p_E)]^{\sigma i} \tag{3}$$

where s_i is the sector i share in the economy output.

Taking into account climatic differences of the economies. Energy intensity of production in various countries can differ from each other due to climatic conditions. To introduce this factor into the model we consider a variable ***DISTE*** being a measure of climate severity: the more severe the climate in a given country is, the higher the variable ***DISTE***.

Further both the intensity parameters of energy factor and the parameters of general efficiency are specified as functions of ***DISTE***: $\alpha_i=\alpha_i(DISTE)$ and $A_i= A_i(DISTE)$ so that $d\alpha_i/d(DISTE)>0$ and $dA_i/d(DISTE)<0$, i.e. in the countries with more severe climate, energy and other production resource intensity of production is objectively higher.

Failures of institutional development and the lack of incentives for energy conservation. In order to include in the model the influence of institutional development on corporate energy conservation incentives and, in turn, on energy intensity levels in different countries, we consider a sector framework of Cournot equilibrium. It is assumed that in any production sector (hereinafter omitting sector indices) there are ***n*** symmetrical firms holding some degree of market power none of which holds a leading position. Their production functions depend on the energy factor ***E*** and some other factors necessary for production process but not for trading and interacting with other companies and organizations within the mechanisms determined by institutional environment. We specify transaction cost of a firm as a total cost of an economic agent on interaction with all his partners (Polterovich, 1999). In such a view it includes some explicit fraction which could be easily taken into account when calculating the total project cost, and a certain implicit fraction being a sum of both monetary but unofficial transaction cost (e.g. bribes) and non-monetary component, such as “efforts”. By our proposition if economic institutions are bad and by this reason the markets are ineffective the total transaction cost could be high especially due to its implicit fraction. As we attempt to show, even having technological options to substitute more expensive production resources (e.g. energy factor) for cheaper ones, firms may fail to implement the corresponding investment projects fearing high implicit transaction costs of their implementation. Further we present a sector model describing equilibrium before the rise in the energy price assuming all the firms symmetrical and equilibrium established after the energy price increase allowing for different reactions of the firms.

We predict that the worse the institutions are in a given economy, the lower the probability of any representative firm reacting adequately to the changes in the factor price ratios and, thus, the lower the number of the firms changing the combinations of the production factors is.

Let $\boldsymbol{Q_j}$ be the output of a sector firm $\boldsymbol{j}$, so, the total sector output is $\boldsymbol{Y}=\sum_{j=1}^{n} Q_j$. The firm $\boldsymbol{j}$ cost function $\boldsymbol{C(Q_j)=cQ_j}$ is identical for all the firms since they are considered symmetrical and if their economic behaviors do not differ. This is our starting point, though in the case of different reactions of two firms to price change their cost functions change differently as well, thus, in this case they are not identical.

We assume a demand function for the sector output is linear and present it in the inverse form:

$$\boldsymbol{P=G-H\cdot Y}, \qquad (4)$$

where $\boldsymbol{P}$ stands for the sector output price $\boldsymbol{G}$ and $\boldsymbol{H}$ denotes positive function parameters. By our proposition this function includes also the competition from the foreign firms.

Consider sector equilibrium before any price shock:

$$\boldsymbol{Q^0{}_j=Q=(G-c)/(H\cdot(n+1))}, \qquad (5)$$

$$\boldsymbol{Y^0=n\cdot Q^0=n/(n+1)\cdot(G-c)/H}, \qquad (6)$$

$$\boldsymbol{P^0=(G+n\cdot c)/(n+1)}. \qquad (7)$$

Now consider a $\boldsymbol{\beta}$ – fold rise in the energy price with $\boldsymbol{\beta>1}$. The proper reaction of a firm, which we term “the adjustment project,” is adjusting its cost to the new price combination by substituting any other production factors for energy. We assume that firms take this course if transaction cost of adjusting is low, and avoid it if the expect transaction cost to be high. Thus, each of the firms considered has to solve the following problem:

$$\boldsymbol{\max \{P^e\cdot F(E,\ldots)-p_E\cdot E-\sum_{j\in J} p_j\cdot X_j-tc\cdot\phi(e_0-E/F(E,\ldots))\}} \qquad (7)$$

$$P^e = G - H\cdot(\sum_{l\in L} Q_l^e + F(E,\ldots)) \qquad (8)$$

where in addition to previous designation, p_j·- denotes the price of a non-energy factor j, X_j – stands for the input of the non-energy factor j, the initial output energy intensity being $e_0=E_0/Q_0$, Y_l^e is an output expected by the firm considered from another company l, J is a set of indices denoting all the used non-energy factors, so that $j\in J$, L – set of indices designating all the firms other than a given one. Thus, the sum $\sum_{l\in L} Q_l^e$ means the expectation of a given firm about the outputs of all $(n-1)$ others and, so, P^e is expected output price depending on this expectation. Function $\phi(...)$ is a Dirichlet type function with $\phi(x)=0$ if $x=0$ and $\phi(x)=1$ in other cases, and the variable $tc=(0, h)$ has only two values - of low and high levels of transaction cost. For simplicity, we assume that low transaction cost does not affect the company's activity at all and it is therefore taken to be zero. If it is high, its level is designated by h, and it is high enough to stop an adjustment project (specifically by the implicit fraction).

After the increase in the energy price, the general set of the firms breaks into two subsets. The first one includes k firms, which face low transaction cost and thus implement the adjustment projects. The second subset consists of $(n-k)$ firms facing high transaction cost and therefore rejecting adjustment behavior.

For convenience of the further discussion, we provide a solution for the situation when transaction costs are high for all the n firms. In this case, all the firms experiencing a rise in the energy price also face a rise in the cost per unit of output, indicated by Δc_1. Thus, the cost per unit of output when a firm faces high transaction cost is $c_1=c+\Delta c_1$. In this case, the equilibrium solution Q^1, $Y^1=n\cdot Q^1$, P^1 differs from the initial one as follows: $Y^1< Y^0$, $Q^1< Q^0$, $P^1> P^0$ due to the new unit cost c_1 is higher than initial level c.

Now consider a case when $k<n$ and, so, k firms adjust their production factors combinations to new the price structure. Each of them reduces the energy intensity of its output by Δe and the cost per unit of output by Δc_2, thus, its unit cost is $c_1-\Delta c_2= c+\Delta c_1-\Delta c_2$[3].

Designate by $\Delta Q^+(k)$ the output increment from the level Q^1 of a firm, which implements the adjustment project , and by $\Delta Q^-(k)$ from this level for the company rejecting it, the argument k in brackets means that k firms implement the adjustment project. The increment of the solution with respect to the level (Y^1, Q^1, P^1) can be calculated as follows:

$$\Delta Q^+(k)=(n-k+1)\cdot \Delta c_2/[H\cdot(n+1)],\ k=1,\ldots, n \qquad (9)$$

$$\Delta Q^-(k)=-k\cdot\Delta c_2/[H\cdot(n+1)],\ k=1,\ldots, n-1 \qquad (10)$$

$$\Delta Y(k)=k\cdot\Delta c_2/[H\cdot(n+1)],\ k=1,\ldots, n \qquad (11)$$

$$\Delta P(k)=-k\cdot\Delta c_2/(n+1),\ k=1,\ldots, n \qquad (12)$$

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[3] Obviously a condition $\Delta c_1-\Delta c_2>0$ holds.

where $\Delta Y(k)$ and $\Delta P(k)$ stand for the increments of the total sector output and the market price correspondingly, given that k firms undertake the adjustment project. It would be natural to assume that $Q^1(k)+\Delta Q^-(k)\geq 0$ for each k, which is guarantied if

$$G\text{-}c^1\text{-}n\cdot\Delta c_2= G\text{-}c\text{-}\Delta c_1\text{-}n\cdot\Delta c_2\geq 0. \qquad (13)$$

This condition seems fairly natural. For instance, if firms' production functions have unit elasticity of substitution, then $\Delta c_2 =[(\beta\text{-}1)\cdot\alpha\text{-}(\beta^{\alpha}\text{-}1)]\cdot c$, with β, as before, standing for the index of energy price increase[4].

Our basic assumption is that the number of the firms facing low transaction cost k is strongly dependent on the quality of institutions: the higher the quality, the higher the number k is. We assume it is zero if institutions are very bad and provide for no incentives for adjustment to energy price change and it is close to n if institutions provide for strong incentives.

PROPOSITION: Let n symmetrical firms having production function of type (1)[5] operate in a given sector and the sector demand function be as (4). Let the sector to reach Cournot equilibrium. After an increase in the price for the energy factor p_E, each firm solves the problem (7)-(8), k firms face low transaction costs associated with the implementation of adjustment projects, and $(n\text{-}k)$ firms face high transaction cost. Then the final value of the sector energy intensity, measured as $\sum_{j=1}^{n} E_j/Y$ is the lower, the higher k is.

PROOF: Let the energy intensity of a firm before the price shock be e_1, then after the energy price increases, the firms, which undertake adjustment projects have energy intensity e_2 with $e_2<e_1$ which holds true by the property of the production function. The value of energy intensity of the firms not undertaking adjustment projects stays e_1. Thus, the value of the sector energy intensity under condition that k firms undertake adjustment projects $e(k)$ is:

$$e(k)=s(k)\cdot e_2+(1\text{-} s(k))\cdot e_1 \qquad (14)$$

with $s(k)$ is a share of the firms undertaking adjustment projects in total sector output. At the same time, obviously, the value of the sector energy intensity derivative by s is negative because $e_2<e_1$. So, it is necessary to prove that $ds(k)/dk>0,$ which is not obvious since the rising number of the firms implementing the project reduces individual outputs of these firms (due to the equation (9)). Construct the value $s(k)/(1\text{-} s(k))$:

$$s(k)/(1\text{-} s(k))=$$
$$[k\cdot Q_1+k\cdot(n\text{-}k+1)\cdot\Delta c_2/(H\cdot(n+1))]:[(n\text{-}k)\cdot Q_1\text{-}(n\text{-}k)\cdot k\cdot\Delta c_2/(H\cdot(n+1))] \qquad (15)$$

Indicate $\theta(k)=k\cdot Q_1+k\cdot(n\text{-}k)\cdot\Delta c_2/(H\cdot(n+1))$ and substitute for into (15):

$$s(k)/(1\text{-} s(k))=[\theta(k)+k\cdot\Delta c_2/(H\cdot(n+1))]:[n\cdot Q_1\text{-}\theta(k)] \qquad (16)$$

Due to the condition (13) the derivative of $\theta(k)$ with respect to k is positive:

$$d\theta(k)/dk=Q_1+(n\text{-}2k)\cdot\Delta c_2/(H\cdot(n+1))=((G\text{-}c_1+(n\text{-}2k)\cdot\Delta c_2)/(H\cdot(n+1))>0 \qquad (17)$$

Taking into account (17) one can find that the numerator in (16) grows and at the same time the denominator reduces as k increases. Thus, the value $s(k)/(1\text{-}s(k))$ is a function growing by k. The

[4] Under α=0.2 doubling of *real* energy price (β=2) leads to the value of Δc_2=**0.0513**.
[5] Sector index i is omitted.

latest fact can be true if and only if $ds(k)/dk>0$. This means that $de(k)/dk<0$ and the proposition is proved.

At this point, we conclude that the weak institutional environment could be considered an important factor undermining the efficiency of energy use. Weak incentives for change of technologies may result from the high cost of market operation. We assume that the value h may be associated with both the market performance itself and its interaction with the government including the quality of the policy measures and the degree of corruption. As we specified before, this value probably includes some monetary component, such as bribes and higher taxes, and the non-monetary component are additional attempts of entrepreneurs for establishing and maintaining agreements.

Another important suggestion we make based on the theoretical framework discussed in this section is a dependence of the demand for energy price elasticity prevailing in a given economy on the quality of institutions. In the model considered, we showed that the sector demand for energy reaction to the energy change is the stronger, the more firms react adequately to the change in the real energy price and, therefore, the stronger the economic institutions are. Thus, it is to be expected that in a given national economy the reaction of the aggregate demand for energy from the production sphere as a whole will demonstrate the same property. For this reason we advance a hypothesis, which will later be tested in the next section of this paper, that the price elasticity of the energy demand of the production sphere is a function dependent on the quality of economic institutions. More specifically, we construct a model of energy intensity of production sector for a particular economy and, therefore, specify the price elasticity of output energy intensity. This coefficient in general differs from the former one.

The first index, at list given the production function with constant returns to scale, captures only the substitution effect. The second one except for the substitution effect allows for wealth effect, i.e. the demand change due to change of the output.

First, if the technology considered actually has constant returns to scale it allows only for the substitution effect of the real price change. Secondly, if some inputs of the production factors cannot change – which is a short-term case – output and total cost change may vary not equally and, therefore, the output energy intensity may change not only due to substitution of other factors for energy, but also due to the variation of the production scale. Moreover, in this situation substitution effect itself may be weaker than in the long run because a certain component of the energy input may be a quasi-fixed factor.

4.3 Specification

We use the following specification:

$$ln(e)=\beta_0+\beta_1\cdot DISTE+\beta_2\cdot INST\cdot ln(P/p_E)+\beta_3\cdot ln(P/p_E)+\beta_4\cdot SHUN95+\varepsilon, \quad (18)$$

though the variable $INST$ may designate different institutional variables from their total list presented in the section 4.1. We use both several individual variables and their combinations. The variable of a combined influence of the real

energy price and institutions ***INST· ln(P/p_E)*** is called the interaction term, which we use following Polterovich and Popov (Polterovich and Popov, 2004). If it proves significant, one could suggest that the institutions affect energy intensity through the price system. On the other hand, a simple transformation in (18) helps to see that the value $[\beta_2 \cdot INST+\beta_3]$ is the price elasticity of output energy intensity as a function of the institutional strength index, which fit our theoretical model.
The last variable ***SHUN95*** is the size of unofficial economy. Adding this variable to the specifications in all the cases drastically improves their quality and without significant changes in the estimate coefficients. Moreover, since its individual significance is not sufficient in all the cases, we provide the both types of the specifications: omitting this variable and including it.
This specification doesn't include any structural variables though the share of services in the total employment has a certain level of significance if the shadow economy size variable is not used. At the same time adding this variable doesn't improve the general quality of the regression estimation. The probable reason why our model is not sensible to the structural variables is the fact that institutional quality indices are very strongly correlated with a per capita income variable. At the same time according to Chenery hypothesis the change of the latter one is closely associated with the change of the economic structure: the higher income economies have the higher share of the services sphere with lower energy intensity as compared to the sphere of goods production.

5. Estimation Results: What are the Main Reasons for High Transaction Cost?

We estimated several models in compliance with the formulated theoretical framework and provided specification. All of them include control variables ***DISTE*** and ***ln(P/p_E)*** but differ by interaction terms and by including or not including the shadow economy variable. Adding the shadow economy variable (see in the Table A2 in APPENDIX) in all the cases sharply improves the significance of the models, though the significance of this variable itself is not ever on sufficient level. The reason why the size of the shadow economy variable is significant and has positive correlation coefficients is quite clear: in the shadow economy the energy consumption is better documented than the generated income. Thus, the higher its share in GDP, the greater proportion of income is omitted from the official statistics and the higher is observed energy intensity of production if other factors are fixed.

Table 1

Estimated Energy Intensity of Production in the World Countries, 2000 (dependent variable: ln(Energy Consumption per unit per GDP unit)

Variables	Version 1, 74 observations		Version 2, 55 observations	
	OLS Model	IVLS Model	OLS Model	IVLS Model
Constant	-.2644 (.1237)	-.0968 (.1817)	-.7080 (.1676) (.1620)*	-.4949 (.2788)
Variable of climate conditions: ***DISTE***	.0025 (.0005)	.0026 (.0005)	.0033 (.0005) (.0005)*	.0033 (.0006)
Real energy price***: ln(P/p_E)*** **	.4046 (.1039)	.6298 (.1993)	.3422 (.1098) (.1703)*	.5758 (.2266)
Interaction term: ***ln(P/p_E)·INST**** **	.1294 (.0476)	.2491 (.1019)	.1075 (.0517) (.0438)*	.2050 (.1267)

Share of Shadow Economy: ***SHUN95***			.7266 (.3620) (.4066)*	.6296 (.6250)
R-squared	0.3574	0.2948	0.5254	0.4692
Adj R-squared	0,3298	0.2646	0.4874	0.4267
F-value	12.98	10.59	13.84 16.34*	11.79
Root MSE	.42609	.44636	.34952	.36963
Hausman test, Chi2		2.10, Prob>chi2= 0.5524		1.67, Prob>chi2= 0.7963
Cook-Weisberg test, Chi2	0.20, Prob>chi2= 0.6522		0.97, Prob>Chi2= 0.3257	

*corresponds to the "Sandwich estimator" model
**instrumented using the logarithm of oil import cost per unit of oil
variable ***INST is the sum of two institutional indices: ***GOEFF*** and ***GRAFT*** ; it is instrumented by infant mortality rate

We calculated interaction terms using the variable of logarithm of real energy price· ***ln(P/p$_E$)*** and indices of institutional price from (http://www.worldbank.org/wbi/governance). It turned out that not all of the resulting variables were significant in explanation of energy consumption sensitivity to energy price change. First two variables ***VOACC*** and ***POIST*** have very low levels of significance (p-values 0.574 and 0.360 respectively) and their adding to the regression reduces its general level. Thus, we conclude that neither voice and accountability, nor political instability and violence conditions are suitable to the problem discussed. We suggest that these mostly political aspects do not play a significant role in creating incentives for energy conservation. From four other indices, as we found from the analysis provided (see Table A2 in Appendix A2), two ones - ***GOEFF*** and are ***GRAFT*** are highly significant. Variables ***REGBU*** and ***RULAW*** demonstrate either significance at 10% coincidence interval, or worse, so, their importance is doubtful but not impossible. We can summaries that in any case just the variables responsible for the interactions between the bureaucracy and business affect the forming high or weak incentives for energy conservation. The role of corruption in defining the energy efficiency of production sectors in OECD countries was analyzed in (Fredriksson, Vollebergh, and Dijkgraaf, 2004). They showed that there is a strong positive correlation between corruptibility and energy use per unit value added. In their theoretical model an important role of the government's willingness to be bribed is stressed but to take it into account they use corruption perceptions index (Transparency International CPI – see in WWW.transparency.de) being similar to the index ***GRAFT*** we used. Probably, a more suitable proxy for corruptibility is just the variable ***GOEFF,*** which measures the quality of bureaucracy and credibility of the government's commitment. At least we could suggest that our results correspond to both the theoretical approach and the empirical findings of the authors referred. They provided a panel data analysis for 11 sectors and 14 OECD countries, our approach is macroeconomic and based on a single time point data, but includes a much broader sample of the economies.

We also suggest two variables being significant in our model – governance efficiency and graft are responsible for the level transaction cost ***tc*** affecting the incentives to undertake energy saving measures. Inefficient and corrupted governments function as a rule in conditions of incomplete and vague legal systems involving additional cost for the firms implementing investment projects associated with making and supporting contracts, lobbying, bureaucratic coordination and "grabbing hands".

The final version of the model of energy intensity, which we deem to be the most appropriate is presented in the Table 1 both including the shadow economy variable (Version 2) and without it (Version 1). The interaction term included into this model is calculated using the variable ***INST*** being itself just the sum of two significant variables ***GOEFF*** and ***GRAFT***. The model was tested for possible heteroskedastisity and endogenity of independent variables. Cook-Weisberg test revealed that the first problem could be important, especially for the second version of the model. For this reason we provided estimate using White estimate of covariance matrix method ("Sandwich estimator" model). It showed that all the factors with the exception of the shadow economy variable are significant at 5 percent level. The last factor – the share of the shadow economy is significant at on the 10 percent level. The price and the institutional variables were correspondingly instrumented by oil input unit cost and infant mortality. The results of Hausman test suggest that effective models should be preferred.

Table 2

Institutions' Quality Indices and Coefficients of Price Elasticity Energy Intensity of Production by Groups of Countries in 2000.

	Indices of institutional strength*	Elasticity
World in Average	0.676	-0.415
OECD economies	3.064	-0.671
Transitional economies	-0.649	-0.272
East European economies	0.305	-0.375
CIS economies	-1.656	-0.164
Russian Federation	-1.370	-0.195

*A sum of two institutional indices: ***GOEFF*** and ***GRAFT***; ranged from -5 to +5

We provide our calculations of price elasticity of production energy intensity both by the groups of the economies (Table 3) and for each country from the sample (Table A3 in Appendix). One can see that these results confirm our theoretical assumption: the better the institutions the stronger consumption of per output unit responds to changes in real energy price. Particularly, in CIS countries, adjustment of energy demand to changes in real energy prices is to be regarded as weak: the absolute value of average price elasticity coefficient of energy intensity is a quarter of that in OECD countries.); in the East European and Baltic countries this value is also visibly lower than in the developed countries though not so crucially ("only" half of the OECD level). This fact means weak incentives of firms for energy conservation and, thus, serves an important reason for the higher energy intensity of production.

6. Conclusion

The energy intensity in the most of the world countries was falling down during the last decades of the previous century. At the same time in former socialist economies it stays essentially higher than the developed countries. In order to explain this phenomenon we suggest a theoretical model of an economic sector including a certain number of firms, which consume energy and face the necessity of implementing energy conservation projects under the condition of uncertain transaction cost associated with this implementation. The high transaction cost completely stops the project but low transaction cost does not affect the behavior of the firms. We show that the inadequate institutional environment leading to a high probability for a firm to be faced with adverse external conditions resulting in the high transaction cost brings about the lack of incentives for energy conservation. Thus, under such a condition, the substitution effect of energy price change is weaker than in tough market environment. This fact means that higher transaction costs worsen the incentives for energy conservation.

Our econometric model permits one to calculate energy price elasticity of production energy intensity, which is a value similar to price elasticity of conditional demand for energy. Analysis showed that two institutional variables from their common list provided in (Kaufmann, Kraay and Zoido-Lobatón, 1999) have high significance levels. They are – “government effectiveness” and “graft”. Using the estimates results we provided coefficients of energy price elasticity of production energy intensity both by the groups of the economies and for each economy from the sample. We show that the average of these coefficients for the group of CIS economies is more than four times lower than that for the OECD economies (by their absolute values); in the East European and Baltic countries this value is also visibly lower than in the developed countries though not so crucially (“only” two times). This fact means weak incentives of firms for energy conservation and, thus, serves an important reason for the higher energy intensity of production.

The main conclusion from our analysis is a primacy of institutional development with respect to special policy measures aimed at energy conservation. The latter would not be efficient enough if market incentives for energy saving are weak. We suggest that to strengthen them the following measurements should be undertaken:

- well recognized measures to protect property rights and to support contracts (development of market legislation, legal systems, opposing corruption),
- improving the quality of economic policy and reputation of the government, a minimization of incidence of market unfriendly policies including price controls and inadequate bank supervision,
- further development of the banking systems and the stock markets,
- improving the corporate governance of the enterprises, strengthening internal control in the firms, setting proper incentive systems for saving of production resources,
- policies supporting small and medium-size firms.

World experiences suggest that in order to strengthen the energy conservation governments may conduct additional special measures to support and intensify energy conservation: subsidize energy conservation projects, standardize energy equipment and support the development of the market of energy conservation technologies. Reform of electricity sector being conducted in a large number of the countries at present time can effect in a reduction of both the fuel consumption in electricity generation and the waste of electric energy during its transportation and distribution. An important role could play hardening of environment legislation and joining the Kyoto protocol.

7. References

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Appendix 1

Table A1

List of Variables

Variables	Contents	Sources
y	Labor Productivity, USA=1	WDI 2001 CD-ROM, ILO: http:\\laborsta.ilo.org
e	Energy Intensity of Production, USA=1	IEA data: http://data.iea.org, 2001 CD-ROM
p_E	Energy Price for Industry, USA=1	http://data.iea.org, WDI 2000 Transition Report EBRD, 200
P	Average output price calculated as a relation of nominal GDP in US$ to PPP GDP	WDI 2001 CD-ROM
	Import Oil Cost per a Barrel, USA=1	http://data.iea.org
DISTE	Season Temperature Fluctuation, in Tenths of Degree Centigrade	IPCC: http://ddcweb1.cru.uea.ac.uk
VOACC	Extent to Which Citizens of a Country Are Able to Participate in the Selection of Governments., (index: -2.5 - +2.5)	http://www.worldbank.org/wb overnance/
POIST	Measures Perceptions of the Likelihood that the Government in Power Will be Destabilized or Overthrown by Unconstitutional Means, (index: -2.5 - +2.5)	http://www.worldbank.org/wb overnance/
GOEFF	Measures Quality of Bureaucracy and Credibility of the Government's Commitment, (index: -2.5 - +2.5)	http://www.worldbank.org/wb overnance/
REGBU	Measures Incidence of Market Unfriendly Policies Including price Controls and Inadequate bank Supervision, (index: -2.5 - +2.5)	http://www.worldbank.org/wb overnance/
RULAW	Measures the Extent to Which Agents Have Confidence in and Abide by the Rules of Society, (index: -2.5 - +2.5)	http://www.worldbank.org/wb overnance/
GRAFT	Measures Perceptions of Corruption, (index: -2.5 - +2.5)	http://www.worldbank.org/wb overnance/
INST	GOEFF+ GRAFT	
SHUN95	Share of Unofficial Economy in GDP for Former Socialist Republics, 1995, %	Friedman, Johnson, Kaufman Zoido-Lobaton, 1999; Alexee and Pyle, 2001
	Infant mortality rate	WDI 2001 CD-ROM