DOES OWNERSHIP STUCTURE MATTER FOR ENERGY EFFICIENCY: A NON-PARAMETRIC STUDY OF THE DETERMINANTS OF ENERGY EFFICIENCY PERFORMANCE IN COUNTRIES IN TRANSITION

by

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Abstract

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Present study is an attempt to answer the question about the impact of ownership structure on energy efficiency of an industrial firm, as well as to determine other driving forces for improvement of energy efficiency in transition countries. A non-parametric approach (DEA) is applied at the first stage to estimate energy efficiency scores measured by input-oriented Shephard-type efficiency, as well as by energy-oriented (sub-vector) efficiency. Truncated regression with smooth homogeneous bootstrap is used as the estimation technique at the second stage of the analysis to identify key drivers of energy efficiency. The obtained results for ownership structure are mostly robust for both overall and sub-vector energy efficiency and show that in general there is negative relationship between size of state ownership in the company and energy efficiency level. The findings imply that foreign ownership, on average, has weak negative impact on estimated efficiency. Such factors as labor quality and involvement into innovation processes are found to have significant positive effect on energy efficiency performance in both efficiency interpretations. Finally, the study provides possible course for further research in the field.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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I dedicate this work to my baby I am expecting now.

Chapter 1

INTRODUCTION

The problem of traditional energy sources depletion, the environmental problem of pollution and recently the tendency to the high energy price volatility (Serletis, 2007) has driven attention of researchers and practitioners to efficient allocation of energy inputs. They focus, like in Martinez (2010), on energy as a special input alongside capital and labor. Appropriate energy inputs usage can be treated as a way to improve an economic agent's total efficiency. Since the industrial sector accounts for more than one third of world energy consumption per year (Greening et al., 2007), industry seems extremely attractive from energy conservation perspective.

Current study is focused on countries in transition notable for high energy intensity as compared to the developed economies. High energy intensity in transition countries can be explained by historical circumstances, including comparatively poor operation of institutions that weaken the influence of incentives and other instruments correlated to energy conservation and environmental issues at the state level (Blackman and Harrington, 1999) and a comparatively easy access to fossil fuel through Russian energy market (Cornillie and Fankhauser, 2004). Furthermore, countries in transition are characterized by a less competitive environment, a considerable share of public sector with soft budgets and state management, especially in the post-Soviet economies (Blackman and Harrington, 1999).

The latter has given rise to the main research question of present study which is as follows: does ownership structure matter for energy efficiency of businesses operating in transition countries? Furthermore, this work aims to investigate the main determinants that force economic agents to maximize energy efficiency understood as the efficient use of energy inputs.

Two measures of efficiency are utilized in the study. Measure of energy-oriented efficiency (sometimes referred to as sub-vector DEA measure) is chosen in such a way that energy costs can be ceteris paribus reduced without negative effect on output and allows the rest of inputs to stay unchanged in the short run, whereas overall input-oriented efficiency implies by definition proportional contraction of inputs (including energy input) given original output level.

To answer the questions of interest non-parametric two-stage data envelopment analysis method is applied in the paper. The data source used is the latest information from the Business Environment and Enterprise Performance Survey. It is collected from about thirty transition countries by the European Bank of Research and Development and the World Bank. I focus on the micro-level markets assuming that market environment where a business entity is operating affects the key drivers of energy efficiency.

The results of this study will help to identify the main determinants of energy efficient operation common for economic agents working in the transition markets. It will be useful for policy makers when they try to determine the optimal initiatives for energy conservation and development and can help to predict what can make a positive impact to the firm-level energy efficiency performance, which in its turn contributes to a sustainable growth of economies.

The remaining part of this paper is organized in the following way. First, I review the literature relevant to the topic under investigation. Next chapters deal with data description and methodology applied. The following part provides discussion of empirical estimation results. The final is the concluding chapter which contains recommendations and possible further topic research extension.

Chapter 1

LITERATURE REVIEW

While one individual can reach a goal easily, another makes a lot more efforts to achieve the same result. Remarkably, the same statement is valid for individual firms that produce outputs by using inputs with a certain technology. The answer to why this is the case is related to the concept of the efficient use of resources employed. So as to develop and fulfill the proper policy, which could reinforce the energy saving behavior among firms as well as other decision-making units it is necessary to be aware of determinants of the efficient energy utilization.

In order to structure the literature on the topic, first, I present an overview on modeling approaches in the field of energy efficiency research; then I proceed to papers, that focus on determinants of energy efficiency performance and highlight works that introduce ownership structure or relevant issues.

Researchers from different scientific fields including industry, business, ecology and economics try to model energy consumption from a variety of perspectives. For the sake of present study it seems enough to focus on the papers written on industrial energy efficiency from economic perspective. Recent study by Greening et al. (2007) groups energy papers by method applied. First group they separate out is based on the decomposition of energy trends implying comparing tendency across subgroups with respect to different underlying drivers. Such technique is mostly utilized as a complement to more standardized econometric methods. Analogous procedure is applied in Cornillie and Fankhauser (2004) who study key drivers of decreasing energy intensity in transition countries. The main points and conclusions of this paper will be discussed later in the chapter. The second related to the issue group of studies subdivided in Greening et al. (2007) is characterized by econometric methods applied. It contain various techniques: simple single equation estimated by OLS as well as quite complicated time series models like in Asafu-Adjaye (2000) who estimated the relationships between energy consumption and income for several Asian countries.

Though there is a large portion of literature dedicated to the energy efficiency, big share of it is written from the perspective of energy security rather that economic science and quite often related studies are more of descriptive nature with little data analysis (Rohdin et al., 2007; Klevas and Minkstimas, 2004). Nevertheless, there is a number of papers investigating the energy efficiency in the manufacturing sector within a particular country in whole, such as the United States (Mukherjee, 2008a), and across regions in developing India (Mukherjee, 2008b). In addition, there are also attempts to find out energy efficiency driving forces for a separate country in transition, for instance, the case of Slovenia (Hrovatin and Urib, 2002).

After all, there is comparatively few studies which focuses on the energy efficiency in transition countries, the exception being Cornillie and Fankhauser (2004) who study key drivers to decrease energy intensity. They focus mostly on trends comparison of the core subgroups of countries at macro level trying to find out if attributed factors differ across time or country groups.

In general, a wide range of factors is examined in the literature to explain (in)efficiencies of a DMU with respect to energy inputs. It is shown in DeCanio and Watkins (2008) that specific characteristics of a firm explain the barriers to energy efficient performance. At the same time, there are features of market that influence firm's energy efficiency performance as well.

First group of factors which is of the high interest for the present study is factors relevant to ownership structure. The earliest introduction of ownership structure notion known to the author belongs to Jensen (1976), which inspired a large number of papers dedicated to the issue, including those investigating causal relationship between ownership and firm's performance.

The process of transition implies transformation of stated-owned enterprises to those with clear property right. Besides, foreign-ownership in transition countries is associated with better overall performance in comparison to state ownership (EBRD, 2005). Moreover, there is empirical confirmation that foreign-owned companies tend to be more efficient in energy conservation (Faruq and Yi, 2010) and, at the same time, there is evidence provided in Zelenyuk and Zheka (2006) that reveals a negative correlation between foreign ownership and firm's efficiency level. Brown et al. (2004) analyze the influence of privatization on the enterprise's productivity by using industrial firm-level panel data of Hungary, Romania, Russia, Ukraine. Moreover, the authors analyze dynamic change in productivity before and after privatization. Brown et al. (2004) conclude that there is a positive correlation between firms' productivity and privatization in Romania, Hungary, and Ukraine, though for Ukraine the effect is much weaker; at the same time in Russia they find even small negative impact. Further, they reveal somewhat different space of the privatization impact within these four countries under investigation, though all these economies' cases showed significant difference between domestic and foreign privatization.

Empirical study by Cornillie and Fankhauser (2004) focuses more deeply on the energy intensity of the emerging markets. They apply decomposition technique to macro-level data and show that energy intensity is different for regions with different rate of privatization. The group of countries with big share of heavy industry like in the Slovakia, Romania and Poland the level of energy intensity stayed constant for the period of investigation from 1992 to 1998. Cornillie and Fankhauser (2004) claim that unchanged level of energy intensity is associated with a big share of heavy industry in the economy as well as poor reforms in the sector. In the group of CIS countries energy intensity increased during the transition period and Cornillie and Fankhauser (2004) link it to inappropriate process of privatization, which was either postponed or didn't lead to improvements of the production process in industrial sector. Besides, unadjusted to the market level energy tariffs is found to be the case. Remarkable inference made that private ownership without access to the innovation technologies and capital inflows is found to be not enough for energy efficiency improvement.

Whereas the ownership structure can be regarded as firm specific and dealt with features of country, the energy prices are mostly set up by the market. Prices of energy sources are one of the most obvious drivers of efficient use of energy inputs. According to the basic law of supply and demand, as the cost of energy input rises, ceteris paribus, producer prefers to employ smaller quantity of energy input and substitute cheaper inputs for more expensive energy during the production process (Schurr, 1982; Jorgenson, 1984). Moreover, there is a certain correlation between the changes in energy prices and additional incentives for technological innovations. The relationship between prices of energy sources and technological process is investigated by setting energy patents as a proxy for innovations. Metcalf (2008) uses price indices and prove that at the state level energy use improvement can be achieved by changing the activity to the one with less energy consumption. Besides, they state that in the long run the energy prices are stated to affect energy intensity significantly though with some lingering.

Another focus is to look for energy consumption patterns and notice that changes in use of energy inputs are strongly correlated with technological development (Rose and Chen, 1991; Murillo-Zamorano, 2005). Therefore, investments into innovations are associated with the efficient energy usage (Groot et al., 2001), as investments can result in saving energy while improving technologies. Another way of contribution to energy efficiency through investments is stated in Martinez (2010). He argues that positive result can be achieved through a "demonstration effect" in business environment.

Among the specific firm level characteristics of overall performance of producer are labor and capital productivity and their ratio. These factors are frequently considered as the significant determinants for energy efficiency (Martinez, 2010, Faruq and Yi, 2010). Incidentally, firms that operate in transition and developing countries are likely to be characterized by comparatively low level of wages and therefore gain an advantage by using labor more intensively than other inputs (Oczkowski and Sharma, 2005). At the same time, over-employment of labor can be the cause of inefficiency as proved in Couto and Graham (2009). Nevertheless, in Lachaal et al. (2005) the impact of labor costs is found to be not significant for the technical efficiency measure, while the share of skilled labor force is significant and positive. Hence, labor quality could be taken into consideration while analyzing firm's performance with respect to energy recourses. Some positive effect is recently proven, for example, in Kim and Shafi'i (2009).

The hypothesis that the size of company can improve energy efficiency is also tested and proven, for example, in Oczkowski and Sharma (2005). In addition, the size of company can be treated as the signal for investments and therefore can play a positive role in the improvement of energy efficiency (Kander and Shon, 2007). Still, the relation between the company's size and efficiency is not straightforward and can be negative as well as positive (Faruq and Yi, 2010). Hence, the marginal impact of firm's volume on energy efficiency is to be verified in the current research for the sample of transition countries.

Different empirical works that study reasons for energy (in)efficiencies pay attention to the market share or value added to the industry output and find the evidence that it can make a contribution to the explanation of inefficiencies as the factor of market power (Hrovatin and Urib, 2002; Soytas and Sari, 2007).

It is worth mentioning, that fossil energy resources are characterized by the considerable undesirable outcome (such as CO_2 emissions) and still their share in total energy generation is dominant[1], while the role of renewable energy sources is comparatively low, though extended recently. Implementation of environmental conservation regulation influences the incentives for green energy and energy efficiency improvement, therefore the existence of undesirable outcomes as well as the level of environmental regulation is to be incorporated while estimating energy efficiency of a DMU (Zhou et al., 2008).

Hence, with given background this research is supposed to contribute to the literature by answering the question about the role of ownership structure for energy efficiency improvement in countries after two decades of transition process based on recent publicly available micro-level data. Besides, this study is aimed to fill the gap in the literature with no systematic micro-level evidence and shed the light on the factors that play the major role in the energy efficiency improvement of the firms that operate in countries after two decades of transition process.

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1 Energy Information Administration, World Energy Outlook 2010, accessed at *http://www.worldenergyoutlook.org/docs/weo2010/WEO2010_es_english.pdf* on December 10, 2010.

Chapter 3

METHODOLOGY

This section is devoted to construction of a theoretical model and estimation description.

3.1 DEA approach

Coelli et al. (1997) enumerates the following principle methods to estimate the best practice production frontier and the efficiency scores of the DMUs: least-squares econometric production models, total factor productivity indices, stochastic frontiers and data envelopment analysis (DEA). Besides, there is a recently introduced approach StoNED (Stochastic DEA) (Kuosmanen, 2006).

In general, two main types of technique can be defined in analyzing the production frontiers: the so called parametric (econometric) and non-parametric (programming) approaches. While parametric approach is mostly concentrated on the average tendency and capable to incorporate statistical noise, the mathematical programming approach is per se enveloping method which doesn't suffer from misspecification problem of the functional form (Fried et al., 2008).

Recent productivity research uses quite actively non-parametric DEA technique; in particular, DEA is applied in the current research. It the first stages of the analysis energy efficiency scores are to be estimated via DEA while true energy efficiency scores are unknown. It the second stage, the impact of hypothesized explanatory variables on the energy efficiency is analyzed.

3.2 Energy efficiency measurement

According to traditional context established by Farrell (1957), two components make up a firm's efficiency: technical (the ability of a firm to minimize waste of given inputs and obtain maximum output under particular technology and output level) and allocative (the ability of a firm to combine inputs in optimal proportions given input prices).

A common practice when dealing with technical efficiency measuring is to concentrate on the input or output orientation of the analysis. This decision depends on the question under research. In order to analyze energy conservation behavior of firms it is reasonable to focus on the input-conserving direction. In other words this research concentrates on the analysis of technical efficiency defined as using the lowest possible level of input within given technology and outputs.

If each firm is considered as a DMU the technology can be formally defined by the technology set in the following way:

$$T=\{(\mathbf{x},\mathbf{y}) \in \Re_{+}^{N} * \Re_{+}^{M} : \mathbf{x} \text{ can produce } \mathbf{y}\}, \tag{3.1}$$

where $\boldsymbol{x}$ is a set of inputs the DMU uses to produce set of outputs $\mathbf{y}$.

Under assumption that each firm within the industry has got access to the same technology (but can use this access efficiently or not), the first step of the analysis aims to estimate how far each particular firm is located with respect to the best possible technological frontier. Besides, output set P**(x)** gives a full representation of technology either:

$$P(\mathbf{x}) = \{\mathbf{y} \in \Re_{+}^{M} : \mathbf{x} \ can \ produce \ \mathbf{y}\}, \mathbf{x} \in \Re_{+}^{N}, \tag{3.2}$$

as well as inputs requirement set L(**y**):

$$L(\mathbf{y}) = \{\mathbf{x} \in \Re_{+}^{N} : \mathbf{x} \ can \ produce \ \mathbf{y}\}, \ \mathbf{y} \in \Re_{+}^{M}. \tag{3.3}$$

The production technology is assumed to satisfy the following main axioms. (Färe and Primont, 1995):

1. "No free lunch": $\mathbf{y} \notin P\ (\mathbf{0}_N), \forall \mathbf{y} \geq \mathbf{0}_M$;

2. "Producing nothing is possible": $0_M \in P(\mathbf{x}), \mathbf{x} \in \Re_+^N$;

3. "Output set is bounded": $P\ (\mathbf{x})\quad is\quad bounded, \forall \mathbf{x} \in \Re_+^N$;

4. "Technology set is closed": *T is closed;*

5. "Free disposability of inputs":

$\mathbf{x}^0 \in L(\mathbf{y}) \Rightarrow \mathbf{x} \in L(\mathbf{y}), \forall \mathbf{x} \geq \mathbf{x}_0, \mathbf{y} \in \Re_+^M$;

6. "Free disposability of outputs":

$\mathbf{y}^0 \in P(\mathbf{x}) \Rightarrow \mathbf{y} \in P(\mathbf{x}), \forall \mathbf{y} \leq \mathbf{y}^0, \mathbf{x} \in \Re_+^N$.

The axioms above are formally presented in terms of P(**x**), output set, but they can be performed in any set-wise form due to equivalence of three main characterization of technology: $(\mathbf{x}, \mathbf{y}) \in T \Leftrightarrow \mathbf{y} \in P(\mathbf{x}) \Leftrightarrow \mathbf{x} \in L(\mathbf{y})$, where T is defined above technology set, P(x) is output set and L(**y**) represents the so called input requirement set.

An alternative way to represent the technology is based on the concept of functional characterization of production technology. Functional characterization of technology under regularity conditions fully represents production technology. Among the most commonly used implicit representation in production theory is the class of distance functions introduced by Shephard (1953). Input distance function (IDF) can be formally presented as follows:

$$D_I(\mathbf{x}, \mathbf{y}) = \sup\{\theta > 0 : (\mathbf{x}/\theta, \mathbf{y}) \in T\}. \qquad (3.4)$$

Another total characterization of technology is output distance function (ODF) introduced by Shephard (1953):

$$D_O(\mathbf{x}, \mathbf{y}) = \inf\{\ \theta > 0 : (\mathbf{x}, \mathbf{y} / \theta \in T\}. \qquad (3.5)$$

It is worth mentioning, that input and output distance functions give a full representation of production technology under common regularity conditions given above.

In case energy is incorporated as an input alongside with labor, capital and intermediate materials, input distance function is appropriate for studying the energy efficiency of firms under given technology. At the same time, according to its definition of IDF, radial contraction of the inputs is assumed to reach the frontier. In some particular economic issues the question of energy efficiency measuring suggests potential reduction of energy consumption (costs) leaving the rest of the inputs fixed in the short run. Formally, this question can be represented with the help of the most general characterization of the technology - directional distance function (DDF) initially proposed by Luenberger (1992), defined as:

$$D_d(\mathbf{x},\mathbf{y} \mid -d_x, d_y) \equiv \sup\{\theta \geq 0 : (\mathbf{x} - \theta d_x, \mathbf{y} + \theta d_y) \in T\}, \qquad (3.6)$$

where $(-d_x, d_y)$ is some nonzero vector that defines the direction in which the distance between the original level (**x, y**) and the "best practice frontier"[2] (optimal performance) is measured.

Moreover, the purpose to measure energy inefficiency scores in contrast to the overall input inefficiency is addressed by the sub-vector input efficiency, which is closely related to the directional distance function and the one, which allows for non-radial contraction of the inputs bundle (Fare, 1994). Formally, sub-vector input oriented distance function (SVDF) can be defined as follows.

Assuming that all DMUs have the same sub-vector of fixed inputs (non-energy inputs: capital, labor and materials) and one variable input (energy),

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[2] Empirical approximation of the true frontier, which is unknown in practice (Fried et al., 2008).

$$EE^j \equiv EE^j(\mathbf{x}^j, \mathbf{y}^{jk}) \equiv \min_\theta\{\theta > 0 : (\theta * \mathbf{x}_e^j, \mathbf{x}_n^j, \mathbf{y}^k) \in T^j\}, \quad (3.7)$$

where for each j-th DMU (j=1, 2…K), EE^j is the energy efficiency score, which indicates the efficient level of the sub-vector $\mathbf{x}_e^j$ needed to produce $\mathbf{y}^j$, if the rest of the inputs (non-energy inputs) are assumed to stay at the same level $\mathbf{x}_n^j$. Furthermore, DEA-estimates following Fare's input sub-vector technical efficiency measure for each firm, $E\hat{E}^j \equiv \min_\theta\{\theta > 0 : (\theta * \hat{\mathbf{x}}_e^j, \hat{\mathbf{x}}_n^j, \hat{\mathbf{y}}^k) \in T^j\}$ can be obtained with the help of linear programming. Linear programming problem under strong disposability of inputs and variable return to scale, formalized in Lansink and Silva (2004), is used in the current research:

$$E\hat{E}^j = \theta^* = \min \theta \quad (3.8)$$

s. t.

$$\hat{\mathbf{y}}'\lambda \geq \hat{\mathbf{y}}^j \quad \text{(i)}$$

$$\hat{\mathbf{x}}_n\lambda \leq \mathbf{x}_n^j \quad \text{(ii)}$$

$$\hat{\mathbf{x}}_e\lambda \leq \theta * \hat{\mathbf{x}}_e^j \quad \text{(iii)}$$

$$\mathrm{I}'\lambda = 1 \quad \text{(iv)}$$

$$\lambda \geq 0. \quad \text{(v)}$$

As long as all of the stated above distance functions, IDF, DDF and ODF, give a complete characterization of technology that makes a researcher indifferent between them on econometric ground. Nevertheless, from the perspective of energy conservation meaning the concept of IDF, for example, implies proportional reduction in all inputs (including energy) while producing given output. Intuitively, it allows determining an optimal bundle of inputs given the current output level. SVDF, in its turn, has another intuitive and appealing interpretation by showing a reduction of energy while holding output and other inputs constant. In case energy input is non-binding there is a possibility for farther decrease of it without reduction in output and leaving the rest of inputs invariable. Hence, in present study IDF as well as SVDF are employed in order to provide evidence for both economic understandings of energy conservation.

3.3 Econometric approach to determination of energy efficiency

The second step of the DEA is focused on the regression analysis to determine the main drivers of the energy efficiency. Hence, the basic empirical model can be expressed as follows:

$$E\hat{E}_j = \alpha_0 + \alpha * Expl + \varepsilon_j, j = 1,...k., \quad (3.9)$$

where $E\hat{E}_j$ is defined as in (3.4) or (3.8) and *Expl* is the set of explanatory variables, that might influence energy performance of a DMU. The list of hypothesized independent variables is represented below and is based on the available data and factors used in relevant literature.

A number of the research papers that employ DEA estimates of efficiency apply Tobit estimator or use OLS for regression[3]. However, Simar and Wilson (2007) give a thorough explanation of the invalidity of the Tobit and OLS estimates for the models with dependent efficiency scores due to serial correlation of the residuals and truncated normal distribution of residuals ε_j ~$N(0, \sigma_\varepsilon^2)$, $\varepsilon_j \geq 1 - \alpha \ D_j$, $j=1,\ldots k$. Hence, to eliminate shortcomings connected to wrong interpretation of the data generating process the truncated regression with bootstrap is applied in the research following the procedure justified in Simar and Wilson (2007) and applied in Zelenuk and Zheka (2006).

According to the algorithm# 1 of Simar and Wilson (2007), first, with the help of maximum likelihood technique, the estimates of parameters and standard deviation of truncated regression are acquired. Then, a parametric bootstrap

[3] see Simar and Wilson (2007) for comprehensive enumeration of examples.

technique is applied to the original estimates and bootstrap results are used to create percentile confidence intervals $[\hat{\beta}_j + a^*_\alpha, \hat{\beta}_j + b^*_\alpha]$ such that, $\Pr(-b_\alpha \le (\hat{\beta}^{**}{}_j - \hat{\beta}_j) \le -a^*{}_\alpha) \approx 1-\alpha,$ where α is a small positive number less than unity, $\hat{\beta}^{**}{}_j$ - bootstrap value, $\hat{\beta}_j$ - j-th element of the parameter β, estimated by $\hat{\beta}$, assuming the number of bootstrap replications $\to \infty$. Simar and Wilson (2007) state that for construction of the confidence intervals 1000 replications is considered to be a satisfactory number. The procedure given above is possible to realize with a number of practical applications, including Stata and Matlab.

In the particular case of this research bootstrap confidence intervals are obtained to test the hypothesis of the specification with the help of 2000 bootstrap replications utilized to improve the inference.

3.4 Determinants of the energy efficiency

Regarding the research question the list of dependent variables starts with the concept of ownership structure, which is widely discussed as a potential determinant of overall efficiency of a firm. Cornillie and Fankhauser (2004) prove that there is some positive correlation between the rate of privatization in transition regions on the one hand, and the change in attitude to energy intensity on the other hand. In the research the hypothesis of dependence between energy efficiency and the share of state ownership in a company is to be tested. Indeed, private companies are more likely to be characterized by profit maximizing behavior and, hence, more interested in energy saving technologies. At the same time, there is a practice of energy efficient stimulation via subsidizing and subsidizing can be regarded as an additional implicit form of government control. Hence, state companies may have access to cheaper credits, and hence, overcome one of the most significant barriers to energy efficient investments (Rohdin et al., 2007). Moreover, their energy projects may be subsidized by the government within national level environmental programs, which means that they can afford ecologically friendly technologies.

Share of foreign capital is another characteristic of ownership structure. Using Ukraine as an example of transition economy, Zelenyuk and Zheka (2006) conclude that there is a negative causal relation between foreign capital and a firm's efficiency. On the other hand, on the assumption that foreign ownership in transition countries mainly originates from the developed western countries it brings high level of corporate management which in turn is associated with the efficient use of resources and, in particular, saving energy.

Another set of explanatory variables is related to the technological development. In particular, statistically significant correlation between the level of firm's investment and efficient energy consumption is hypothesized. The hypothesis relies on assumption that due to volatility of energy prices a certain share of investment projects in corporate sector must be aimed at energy conservation (EBRD, 2010[4]). Besides, it has already been proven that energy intensity can be declined through the so-called spillover effect of the technological modernization within an industry or a region (Rose and Chen, 1991). Information on access to the up to date foreign technologies may also be an interesting issue in the context of innovations.

Furthermore, following the procedure of Martinez (2010) I am going to verify if the size of a company matters for energy intensity. Rohdin et al. (2007) found

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[4] European Bank for Reconstruction and Development. "Corporate energy efficiency" accessed at *http://www.ebrd.com/pages/sector/energyefficiency/sei/corporate.shtml* on February 13, 2011.

that small enterprises in Swedish foundry sector have limited access to environmental government activities. Kander and Schon (2007) in their turn show that bigger firms within an industry are more likely to receive capital inflows. Moreover, to optimize costs small business entities may abandon energy department or single specialists on the matter and underestimate energy efficiency potential of the firm or suffer from shortage of information on the issue.

Another potential explanatory variable is the quality of labor involved. Labor productivity is the most general form of the proxy for this variable (Martinez, 2010). Additionally, such information as the share of skilled labor force or ability of staff to use modern computer equipment can help to clarify the subject as well.

There is a common practice to explain energy efficiency level by energy price volatility (e.g. Martinez, 2010), but in present research energy inputs are proxied with energy costs (annual spending on the fuel and electricity), as well as non-energy inputs with annual labor costs, cost for materials and capital, therefore energy variable incorporates prices at the stage of calculating energy efficiency scores. Hence, there is no reason for including prices as explanatory variable into the second-stage regression. For the same reason the potential influence of capital and labor ratio employed are skipped. To be extremely accurate it should be mentioned that dealing with financial data results in combining the technical and allocative efficiency concepts, which is practiced and intuitively justified in Zelenyuk and Zheka (2006).
Finally, I am planning to include a set of dummies, such as country dummies to monitor specific environmental regulations, industry dummies to monitor the level of competition and specific regulations, as well as time dummies for the year when the survey was being implemented, to control for the market environment and other year specific features, including those caused by late-2000s financial crisis.

Chapter 4

DATA DESCRIPTION

The unbalanced panel data from the Business Environment and Enterprise Performance Survey (BEEPS) are used in this research. This survey is conducted by the European Bank for Reconstruction and Development (EBRD) and the World Bank across twenty nine transition countries examining more than 28 000 enterprises in 2002-2009. The survey is conducted in several waves: information of the original number of face-to-face interviews with business owners or top managers can be found in Table A1 (Appendix A).

According to the EBRD the main aim of the BEEPS is to acquire response from enterprises on business environment in transition countries. The form of personal interview helps to tackle the problem of scarce data, typical for transition countries.

The information regarding the dependent variable, which proxies for the energy efficiency, is taken from answers to questions such as "Total annual cost of fuel", "Total annual cost of electricity". To proxy for the output the question "Last complete fiscal year's total sales" is used. Questions "Total annual cost of labor", "The net book value of machinery, vehicles and equipment", "Total annual cost of intermediate materials" stand for costs of non-energy inputs, labor, capital and materials respectively.

The other set of questions is used to proxy for the explanatory variables. It starts with the question used to proxy for the establishment ownership structure: "What percent of this firm is owned by each of the following: private domestic individuals, companies or organizations; private foreign individuals, companies or organizations; government/state; other (%)". To avoid collinearity problem, only the information on share of private foreign ownership and government share are incorporated into the regression. Additional information of indirect government support is to be received from the following issue reply "Over the last 3 years, has this establishment received any government subsidies?"

The quality of labor involved in the company can be characterized by the answer to the following questions. The share of skilled labor can be obtained from dividing "Number of fulltime employees who were skilled productive workers at the end of last fiscal year" by "Number of permanent, full-time employees of this firm at the end of last fiscal year". Another question that describes the quality of labor force as well as to some extent the level of technological progress is "Share of establishment's workforce that regularly uses computers in their job".

Information of new products share is of good use to characterize the firm's level of innovations. The following question is used to proxy for it: "In the last three years, has this establishment introduced new products or services?". Another question is "Total annual expenditure for purchases of equipment in last fiscal year?", which stands for specific technological development of the enterprise. Besides, access to the up to date foreign or domestic technologies has a potential for energy conservation.

In addition, regarding the so called spillover effect requires incorporating information on the involvement into international trade: answer to the question about "Main market in which the main product or service in last fiscal year is sold" stands for it in the present study.

Unfortunately not every firm involved in Surveys provides complete information. For a big number of firms answers to some questions are not reported for one or several factors. In case of underreported factors for any firm in the data set the energy efficiency scores cannot be calculated or the results obtained are incorrect as can be concluded from (3.4) and (3.8). Hence, I totally excluded information from the Surveys of 2002 and 2005 since there were no results for annual cost of materials, cost of energy used per year, including electricity and fuels or annual total cost of labor; or information on firm's capital is not available. Finally, energy efficiency scores are calculated for the data set of 1854 firms in the period of three years (2007, 2008 and 2009).

Following Martinez (2010) annual sales is included into the regression as explanatory variable. In addition, the enterprise volume is controlled by size dummies. The size of a company is estimated by screener and corresponds to the following three categories: "Small", if there are more than 5 but less than 19 employees, "Medium" stands for the companies with more than 20 but less than 100 employees , and, "Large" is a company with more than 100 employees.

Information necessary to control for the country, industry and year of the survey is also available with answers to the questionnaire.

After observations with missing information on energy sources are dropped the sample includes only the data of the surveys conducted in 2007, 2008 and 2009. Most observations (57%) come from the survey of 2009, the latest one of BEEPS (see Figure 4.1).

For example, in 2009 (the most represented year) the majority of enterprises in the final sample come from Food sector (23%) (see Figure 4.2) and Other manufacturing sector (22%). Fabricate metal products firms number nearly 14%, while 11 % (234 DMU) are from Garments.

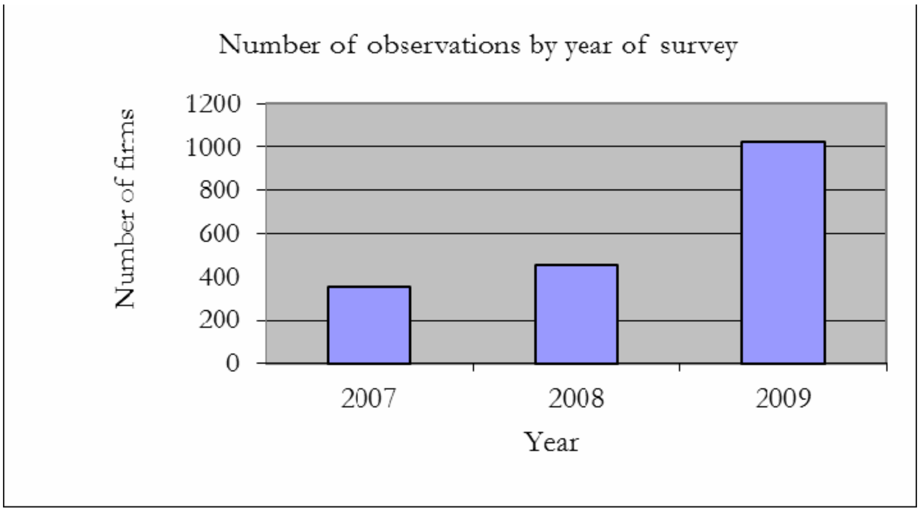

Figure 4.1 Number of firms per year of survey.

These sectors are considered comparatively energy intensive. Remarkably that Chemicals (about 6%) and Non metallic mineral products sector (about 5%) are represented in the final data sample as these sectors are considered to be among top energy-intensive sectors in the World[5]. Information of industry distribution across years of survey subsamples is available in Table A2 (Appendix A).

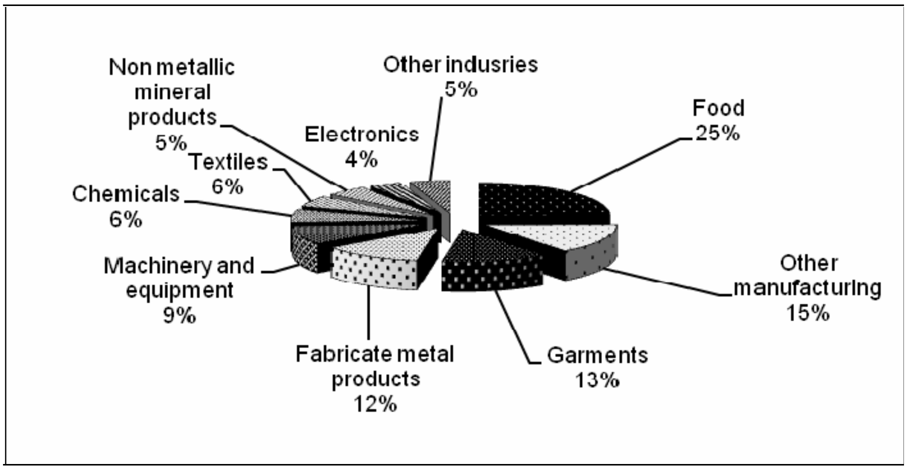

Figure 4.2 Shares of firms by industry in 2009.

5 U.S. Energy Information Administration, "International Energy Outlook 2010. Industrial Sector Energy Consumption" accessed at *http://www.eia.doe.gov/oiaf/ieo/pdf/industrial.pdf* on May 16, 2011.

All countries from the initial survey data are represented in the final sample (see Figure 4.3). There are 28 countries represented in total. 37% of the final sample comes from Turkey (14%), Bulgaria(13%) and Russia (10%). The least represented group of five are Albania, Montenegro, Belarus, Tajikistan and Slovakia with about 1% of the sample per each country.

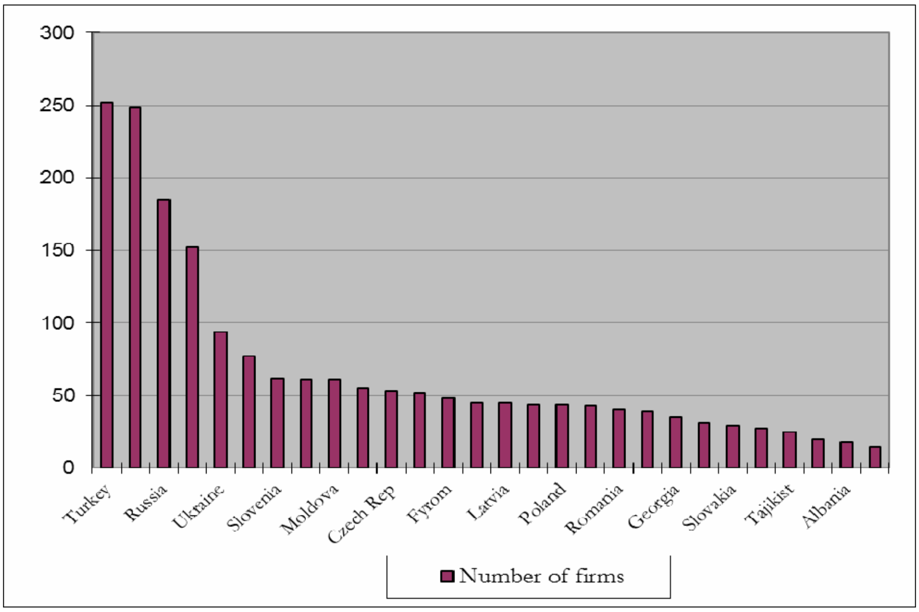

Figure 4.3 Number of firms by country in the sample.

Information on size of the companies is available in Table A5 (Appendix A). For the DMUs, where information on size (4 observations) is not reported, the replacement is done on the base of number of workers. On the contrary, missed values are replaced with figures from the size category range for observations (2 firms) with lack of data on the number of workers.

The summarized information on specific questions used to proxy for dependent and explanatory variables of interest is provided in Table B1 (Appendix B). Descriptive statistics for main variables is represented in the following Table 4.1.

Table 4.1 Descriptive statistics (Survey years 2007, 2008 and 2009).[6]

Variable	Obs.	Mean	Std. Dev.	Min	Max
Annual revenue per worker [7]	1831	187 938	983 457	0	33 100 000
Net book value of capital per worker	1831	53 270	417 896	0	13 900 000
Annual labor costs per worker	1831	31 179	479 724	3	2 030 000
Annual costs on fuel and electricity per worker	1831	6 090	40 926	0	1 456 763
Annual cost of raw materials per worker	1831	63 783	205 811	0	3 191 302
Annual spending on investments per worker	1831	15 599	96 866	5	3 103 456
Number of workers	1831	142	291	5	4 263
Share of workers using computers, %	1831	21%	25%	0%	100%
Share of skilled labor	1831	54%	25%	0%	100%
Share of private domestic ownership (%)	1831	87%	31%	0%	100%
Share of private foreign ownership (%)	1831	10%	28%	0%	100%
Share of state ownership (%)	1831	2%	10%	0%	99%
Other ownership type (%)	1831	1%	10%	0%	100%
Dummy for foreign technology licenses	1831	76,4%-No		23,6%-Yes	
Dummy for government subsidies	1831	86,4%-No		13,6%-Yes	
Dummy for selling mainly in international market	1831	79,0%-No		21,0%-Yes	
Dummy for introduced new products	1831	44,5%-No		55,5%-Yes	
Number of countries					28
Number of industries					11
Years					2007-2009

The data represented in Table 4.1 indicate that the sample comprises enterprises of quite a different volume. The average annual revenue per worker for the company is approximately 188 thousand international dollars, whereas standard

[6] EBRD-World Bank Business Environment and Enterprise Performance Survey (BEEPS) accessed at *http://www.ebrd.com/pages/research/economics/data/beeps.shtml* on 01 February 2011. *Author's calculations.*

[7] Fiscal variables are represented in the international dollars 2007, 2008, 2009. *Author's calculations.*

deviation shows significant variability of about 980 thousand international dollars. The same is relevant for other fiscal terms. Such high variability is not appropriate for predictions based on the sample mean, but for the sake of efficiency scores calculation is suitable as the estimation is made for separate industries, time periods and countries. Besides, dummy variables are incorporated at the second stage of the DEA analysis to control for heterogeneity and effect of scale within the sample. Investments and annual revenue as explanatory variables are taken in logarithms while percentile explanatory factors, such as ownership share, are expressed in percentage. On average, the share of state ownership is extremely low in the final sample (less than 2%). Possible explanation could be that all interviewed private companies are more transparent in transition countries and ready to share information for the sake of international surveys in comparison to state owned enterprises. Summary data on basic positive measure of energy intensity, energy cost relative to annual sales, is shown in the following Table 4.2:

Table 4.2. Energy costs relative to total annual sales by industry.

Industry\Year	2007	2008	2009
Food	0.058	0.085	0.078
Other manufacturing	0.064	0.056	0.047
Garments	0.037	0.045	0.047
Fabricate metal products	0.033	0.138	0.055
Machinery and equipment	0.042	0.043	0.033
Chemicals	0.039	0.077	0.048
Textiles	0.055	0.052	0.072
Non metallic mineral products	**0.117**	**0.089**	**0.090**
Electronics	0.062	0.037	0.034
Plastics & rubber	n/a	0.031	0.059
Basic metals	0.013	0.025	0.065
Average	**0.052**	**0.062**	**0.057**

Energy cost per total annual sales across the sectors observed within 2007-2009 is approximately 6%. The highest energy intensity in the sample is observed for

Non metallic mineral products (0.120 in 2007) and Fabricate metal products (about 0.140 in 2008), while Basic metals sector is characterized by the lowest values (0.013 in 2007, 0.025 in 2008). According to the sample data the average energy intensity is growing in time, though energy is used more intensively on average in 2008 in comparison to 2009 (possible reason is World economic crisis).

Chapter 5

EMPIRICAL RESULTS

As mentioned above the estimation procedure will consist of two stages. The core purpose of the first part of chapter below is to report and discuss the results obtained at the first stage estimation procedure (DEA) for overall input-oriented efficiency and for energy-oriented (sub-vector) efficiency. The second section is dedicated to the discussion of the results obtained at the second stage of the analysis while applying truncated regression with bootstrap.

5.1 Efficiency scores estimation

To determine the main drivers of energy efficient behavior of enterprises in given countries, energy efficiency scores are to be measured at the first stage of analysis. While true energy efficiency scores are unknown DEA is applied to estimate the scores.

Taking into consideration heterogeneity of firms across countries, industries and years, scores are obtained within these main groups of observations. This division is made in order to control for variation between groups. Regarding the assumption that each firm within the industry has got an access to the same technology, I control for the industry of operation while applying DEA technique. Besides, though the time period of analysis is comparatively short (3 years), the World financial crisis of 2008 tracked and deepened the time heterogeneity of data within the period of late 2000-s. Hence, it is reasonable to subdivide groups of observations by the year, when the regarding survey took place, in order to measure energy efficiency scores. Finally, 28 transition economies under investigation are at the different level of development (Cornillie and Fankhauser, 2004) , thus, for analysis they are supposed to be subdivided at least into clusters. For the sake of our investigation beholding each country separately is even more informative.

Input-oriented firms' technical efficiency scores, according to Shephard (1970) measure (3.4), are represented in Table 5.1. Values of efficiency scores θ represent maximum proportional contraction in every input (including energy input), which could be implemented without reducing output. For the aggregate industrial sector the average efficiency in 2007-2009 for a given sample of firms is 1,81.

Table 5.1 Summary statistics of input-oriented efficiency scores before and after trimming of 1%.

	Obs.	Mean	Median	Std. Dev.	Min	Max
Efficiency Scores. Total	1831	1.810	1.00	2.173	1.000	36.470
Efficiency Scores. Trimmed	1812	1.654	1.00	1.329	1.000	9.410

The results obtained go along with theoretical background. According to the definition of input oriented measures values of scores are to be equal or greater than one (the more efficient is the DMU from energy conservation perspective – the less is the energy efficiency score): ones are scores for firms on the best practice frontier. Fraction of inefficiency can be straightforwardly computed as (1-θ)*100%, i.e. the average inefficiency for the given sample is about 44%.

Results of the input-oriented efficiency scores estimation for separate industrial sectors across the time horizon are provided in Table 5.2. The major part of industrial scores is below average value, while Food sector, Machinery and equipment are set beyond typical rate (see Table 5.2).

The maximum value for input oriented efficiency measure is extremely high (36,47 (see Table 5.1)). In order to detect if there are any outliers in the sample Kernel estimated density (KED) of input-oriented efficiency scores is build according to the procedure represented in Salnykov (2005).

Table 5.2 Input-oriented efficiency scores for industrial sectors.

Industry\Year	2007		2008		2009	
	Mean	St. dev	Mean	St. dev	Mean	St. dev
Food	**2.417**	1.633	**2.122**	1.919	1.662	1.511
Other manufacture	1.085	0.168	**2.532**	2.555	1.663	1.518
Garments	**2.142**	1.521	1.383	0.806	1.369	1.103
Fabricate metal products	1.597	0.745	1.463	0.903	**2.146**	2.677
Machinery and equipment	1.434	0.687	**3.390**	5.767	**2.525**	5.512
Chemicals	1.050	0.110	**2.780**	2.866	1.464	0.962
Textiles	1.028	0.089	**1.898**	1.415	1.000	0.000
Non metallic mineral products	1.000	n.a	1.741	1.364	1.009	0.059
Electronics	1.195	0.430	1.348	1.100	1.006	0.028
Plastics & rubber	n/a	n/a	1.000	0.000	1.080	0.199
Basic metals	1.000	n/a	1.000	0.000	1.000	0.000
Average	**1.395**	**0.673**	**1.878**	**1.700**	**1.448**	**1.234**

Figure C1 (Appendix C) represents KED for the total sample as well as the one for the trimmed at 1 % from the right tail. It can be easily noticed on the graph that the right tail is outlying. Outliers could be here due to several possible reasons: measurement error (data are taken from surveys based on interviews), hypothesized outliers could face different distribution of efficiency or face some temporary unobserved difficulties during the period under investigation. Theory suggests trimming data in such cases (Zelenyuk and Zheka, 2006). Trimming at about 1% tails is possible for this particular case; as a result the median and mean are close to the sample efficiency scores. Summary on efficiency scores after trimming is available at Table 5.1. For the sake of better rate of convergence of maximum likelihood estimation nineteen observations are not used in further estimation (approximately 1% of the total sample).

Energy-oriented (sub-vector) inefficiency measure in contrast to overall input-oriented inefficiency does not require proportional reduction of all inputs for DMU. In particular, energy-oriented (in)efficiency, calculated according to (3.8), allows for non-radial contraction of energy input without demoting other inputs under constant level of output. Since other inputs are set to be stable the expected values for energy-oriented (in)efficiency scores are supposed to be higher than in case of overall input-oriented (in)efficiencies. Results of the sub-vector (energy-oriented) energy efficiency scores estimation can be summarized as follows in Table 5.3.

Table 5.3. Summary statistics of sub-vector efficiency scores before and after of trimming 4%.

	Obs.	Mean	Std. Dev.	Min	Max
Energy Efficiency Scores. Before trimming	1812	7.781	31.302	1.000	500.00
Energy Efficiency Scores. After trimming	1740	3.719	5.419	1.000	31.250

From theoretical point of view the results obtained are reasonable. The values are greater than one as the definition of input oriented Shephard-type measure predicts (ones are the scores for firms on the best practice frontier). At the same time, variation of scores is high. One of the possible reasons for it is non-radial contraction within sub-vector DEA procedure. Another point is presence of outliers as estimated scores are received from original (not trimmed) sample. Kernel visualization in Figure C2 (Appendix C) proves that 4% right tail of estimated density could be omitted without significant loss of estimation accuracy. After trimming variation is significantly lower, maximum value of energy efficiency score is about 31, which corresponds to the inefficiency level under non-radial energy conservation of approximately 96 per cents.

5.2 Regression analysis of energy efficiency variation

At the second stage of the investigation truncated regression analysis of the equation (3.9) is employed in order to find out the impact of ownership structure on energy efficiency and to determine main drivers of energy efficiency in transition countries during the investigated period. Two models are estimated at the second step of estimation. The first one includes as a dependent variable the efficiency scores calculated according to (3.4). This model represents input-oriented technical (with elements of allocative) efficiency of DMUs. In the second model dependent variable (calculated according to (3.8)) stands for energy-oriented technical (with elements of allocative) efficiency under non-radial energy input contraction. The estimations are made in order to capture the influence of independent variables on these efficiency measures as they have different economic interpretation behind them.

Obtained results for truncated regression estimation of model 1 and model 2 are reported in Table 5.4 (for detailed results see Appendix D). Both specifications include almost the same set of explanatory variables. The data are studied for collinearity; as a result time dummy variable for 2009 and industry dummy for Basic metals sector are excluded from regression in model (1) meaning that most of their effects are captured by other factors. The rest of time, industry and country dummy variables are significant at 5% level. Result s of estimation of model (1) with input-oriented efficiency as dependent variable show that coefficients at the ownership structure variables are statistically significant based on the bootstrap confidence intervals.

Table 5.4. Results of truncated regression analysis for input- and energy-oriented efficiencies.

Explanatory variables	Input-oriented efficiency model			Energy-oriented efficiency model		
		Bootstrap confidence intervals			Bootstrap confidence intervals	
	Est. coef.	Lower 5%	Upper 5%	Est. coef.	Lower 5%	Upper 5%
Share owned by foreign	0.005*	0.005	0.005	0.046*	0.046	0.046
Share owned by state	0.056*	0.056	0.056	0.009*	0.009	0.009
Log(total annual sales)	0.016*	0.016	0.016	1.413*	1.413	1.413
Log(investment)	-1.165*	-1.173	-1.164	-4.237*	-4.237	-4.237
Share of labor using comp.	-0.005*	-0.005	-0.005	0.004*	0.004	0.004
Skilled labor (%)	-10.205*	-10.271	-10.191	0.795*	0.795	0.795
Medium	0.100*	0.099	0.100	0.027*	0.027	0.027
Large	4.848*	4.804	4.851	0.594*	0.594	0.594
New product	-0.334*	-0.336	-0.334	-0.644*	-0.644	-0.644
Dummy for subsidy	-0.442*	-0.445	-0.442	-0.052*	-0.052	-0.052
Main market: international	-0.349*	-0.351	-0.349	0.002*	0.002	0.002
Dummy for foreign technology	-0.003*	-0.003	-0.003	0.075*	0.075	0.075
Survey_year_2008	-0.410*	-0.410	-0.407	-44.978*	-44.978	-44.978
Survey_year_2009	n/a	n/a	n/a	-62.506*	-62.492	-59.381
Food	-0.027*	-0.027	-0.026	17.314*	17.314	17.314
Textile	-2.401*	-2.405	-2.389	-1.224*	-1.224	-1.224
Garments	0.119*	0.118	0.119	-0.481*	-0.481	-0.481
Chemicals	-0.170*	-0.170	-0.169	-0.116*	-0.116	-0.116
Plastics and rubber	-4.390*	-4.581	-4.390	0.499*	0.499	0.499
Non met. min. prod.	-1.999*	-1.999	-1.978	0.136*	0.136	0.136
Basic metals	n/a	n/a	n/a	10.263*	10.263	10.263
Fabricated met. prod	0.094*	0.093	0.094	-0.155*	-0.155	-0.155
Machinery and equipment	4.820*	4.775	4.821	-3.268*	-3.268	-3.268
Electronics	-1.278*	-1.278	-1.267	0.238*	0.238	0.238
σ_{ε}^{2}	13.533*	13.404	13.533	19.568*	19.568	19.568
# observations	1812			1740		

Notes: (i) * significance at the 5% level according to confidence intervals estimated via bootstrap. (ii) Estimation according to the Algorithm 1of Simar and Wilson (2007). # of bootstrap replications: 2000. (iii) Country dummies (included but not reported) are significant at 5% level.

As expected, coefficient at state ownership has positive sign indicating that higher government share makes contribution to firm's inefficiency level. This fact is consistent with findings in the previous studies. At the same time, Share of foreign ownership according to the estimation results makes a positive significant effect on firm's inefficiency either. This proves findings by Zelenyuk and Zheka (2006), but contradicts with other evidence proved recently (EBRD, 2005). Hence, the hypothesis of negative influence of state ownership on firm's efficiency cannot be rejected, while the evidence for expected positive influence of foreign ownership is not found for transition countries across selected industries. Nevertheless, the value of coefficient at foreign ownership variable is low; it suggests that negative impact of foreign ownership on average is small enough and could be explained by contrary impact in the countries under investigation. Remarkably, results for ownership structure variables are robust across both model specifications. Since, the level of foreign ownership influence is comparatively higher for sub-vector efficiency model while state negative effect is lower in terms of energy-oriented efficiency. These findings reveal that firms from selected industries are better performed if they have lower state owned share. It also supports previous result (Brown et al., 2004). Alongside with other findings of the research possible intuition may be that foreign firms in transition countries are concerned with energy efficiency with less environmental responsibility, thus being oriented mostly to short-term goals, hence, prefer not to invest in energy conservation technologies. Another possible explanation is mentioned in Zelenyuk and Zheka (2006) with respect to total efficiency level of Ukrainian business. They conjecture that foreign capital might be local capital overflowing back from offshore zone.

Examining dummy variable that stands for government subsidies for a particular firm one can observe that on average it is positively correlated with the efficiency in model 1 (negative sign of the coefficient) and makes positive contribution to the efficiency level of firm in terms of overall input-oriented efficiency measure. This result allows concluding that government subsidies enable to increase the level of overall (including energy) input-oriented efficiency implying technological improvement.

To reflect the quality level of labor force variables Share of skilled workers and Share of labor using computers in their job are employed. Both repressors are significant and their coefficients show positive correlation with dependent efficiency scores in the first model specification. This proves earlier findings of Kim and Shafi'i (2009) that quality of labor force plays significant positive role in firm's performance. Besides, such a result contributes to the inference that possible energy efficiency improvement is correlated with additional knowledge about energy conservation behavior, which in its turn is associated with the level of labor quality.

Different empirical studies report that efficiency is likely to be dependent on size of enterprise. All factors included into regression to reflect the size of DMU are statistically significant in the first model suggesting lower efficiency performance of larger enterprises. This result is controversial with the previous studies that show positive effect of firm's volume on efficiency performance in the developed countries regarding signaling effect based on the assumption that large companies gain an advantage at attracting investments. Given result may imply a certain barrier of outsized companies to be governed properly due to the principal- agent problems and suggests specific firm size for optimal input-oriented efficiency level.

The effect of innovations expressed by dummy for introduced new product within the last three years and investments variable has a positive impact on efficiency performance, which is significant at model 1 specification. The results obtained imply that firms, which are more involved in innovation process, experience overall improvement effect if investments and innovations are implemented properly. This outcome is consistent with the recent study of Martinez (2010), who refers to investments as "fundamental" drivers of energy efficiency in Columbia and Germany. Besides, as model 1 suggests, involvement into international trade positively affects efficiency level of the company.

As can be noticed from the results of model 2 estimation, government subsidies for a particular firm make positive contribution to the energy-oriented efficiency level of DMU. This result provides us with conclusion that subsidies enable to increase not only overall efficiency but open up possibility for direct energy conservation not requiring technological development.

Remarkably, second specification suggests, that quality of labor force plays significant but negative role in firm's performance in terms of direct energy efficiency. Here the choice of variables that stand for quality of labor appears to be of major importance. Shares of skilled labor and labor using computers may demonstrate energy conservation behavior but contribution into higher energy consumption may prevail over. It should also be noticed that results of model 2 estimation suggest that DMU size effects efficiency performance in the same negative direction as the first model does, though for sub-vector energy efficiency the impact is weaker. The outcome from second specification indicates that firms involved into international trade and those with foreign technologies used have less potential in terms of sub-vector energy efficiency implying that market penetration as well as implementation of know how is associated with temporary rise of energy consumption.

Chapter 6

CONCLUSIONS

This study employs DEA to determine energy efficiency of industrial enterprises in transition countries based on recent micro-level data. Two DEA energy efficiency measures are estimated: input- and energy-oriented (sub-vector) efficiencies. The choice of applicable measure is related to the purpose of analysis: when the aim is energy saving alongside with reducing other inputs involved overall input-oriented measure is useful, whereas the second measure is appropriate from the objective of environmental regulations and energy conservation behavior of economic agents.

A second-stage regression analysis empirically supports that there is a significant relationship between ownership structure and energy performance of an enterprise. This finding reveals that firms are better performed in energy efficiency terms if they have lower state ownership share. At the same time, there is a weak though significant negative association with foreign ownership and firm's efficiency level implying that foreign companies are less concerned with energy efficiency than domestic business in transition countries. Besides, labor quality, subsidizing and involvement into international trade and innovations are found to be significant for efficiency performance.

Finally, for further research it would be useful to employ more information on the sources of foreign capital and extra indicators of investment goal. One may also improve method applying bootstrap procedure to correct for bias not only regression coefficients but to obtain bias corrected estimates of the DEA efficiency scores in order to develop instruments for optimizing energy consumption in industrial sector of transition countries.

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APPENDIX A

Table A1. Original number of enterprises observed within the surveys.[8]

Years	2002	2005	2007	2008	2009
Number of observations	6153	10421	1952	3375	7482

Table A2. Shares of industrial sectors in the sample.

Industry	Number of firms	Share of industry in total sample	Share of industry in sample after separated industries excluded
Food	463	25%	25%
Other manufacturing	278	15%	15%
Garments	243	13%	13%
Fabricate metal products	230	12%	13%
Machinery and equipment	167	9%	9%
Chemicals	118	6%	6%
Textiles	101	5%	6%
Non metallic mineral products	91	5%	5%
Electronics	68	4%	4%
Plastics & rubber	52	3%	3%
Basic metals	20	1%	1%
*Construction**	*7*	*0.38%*	*excluded*
*Retail**	*6*	*0.32%*	*excluded*
*Hotel and restaurants**	*6*	*0.32%*	*excluded*
*IT**	*2*	*0.11%*	*excluded*
*Other services**	*1*	*0.05%*	*excluded*
*Transport**	*1*	*0.05%*	*excluded*
TOTAL	**1854(1831*)**	**100%**	**100%**

* After industries with small number of observations excluded.

[8] EBRD-World Bank Business Environment and Enterprise Performance Survey (BEEPS) accessed at *http://www.ebrd.com/pages/research/economics/data/beeps.shtml* on 01 February 2011. *Author's calculations.*

Table A3. Shares of firms by country in the sample.

Country	Number of firms	Share of country
Turkey	249	14%
Bulgaria	246	13%
Russia	182	10%
Croatia	149	8%
Ukraine	92	5%
Serbia	77	4%
Slovenia	59	3%
Kazakhstan	57	3%
Moldova	57	3%
Estonia	51	3%
Lithuania	48	3%
FYROM	47	3%
Bosnia	45	2%
Poland	42	2%
Azerbaijan	42	2%
Czech republic	41	2%
Hungary	41	2%
Latvia	41	2%
Uzbekistan	39	2%
Romania	37	2%
Georgia	33	2%
Armenia	31	2%
Kyrgyz	27	1%
Slovakia	27	1%
Tajikistan	25	1%
Belarus	20	1%
Montenegro	14	1%
Albania	12	1%
TOTAL	**1831**	**100%**

Table A4. Shares of observations by the survey year in the sample.

Year of survey	Number of observations	Share in the sample
2007	351	19%
2008	458	25%
2009	1 022	56%
TOTAL	**1 831**	**100%**

Table A5. Shares of firms by size in the sample.

Size of the enterprise	Number of firms	Share in the sample
small(<20)	461	25%
medium(20-99)	706	38%
large(100 and over)	664	36%
TOTAL	**1 831**	**100%**

APPENDIX B

Table B1. Variables description.

Variables	Variable code	Descriptive question in the BEEPS questionnaire
Dependent variable components		
Costs on fuel (last fiscal year)	n2f	Total annual costs of fuel in last fiscal year
Costs on electricity (last fiscal year)	n2b	Total annual costs of electricity in last fiscal year
Total labor costs(last fiscal year)	n2a	Total annual costs (incl. wages, salaries, bonuses, etc) labor in last fiscal year
Net book value of capital	n6a	Net book value of machinery vehicles, and equipment in last fiscal year
Annual cost of raw materials and intermediate goods	n2e	Cost of raw materials and intermediate goods used in prod. in last fiscal year
Annual sales (last fiscal year)	d2	In last fiscal year, what were this establishment's total annual sales?
Exchange rate	er	n\a
Explanatory variables		
Ownership structure		What percent of this firm is owned by each of the following:
	b2a	Private domestic individuals, companies or organizations
	b2b	Private foreign individuals, companies or organizations
	b2c	Government/state ownership (%)
	b2d	Other ownership type (%)
Size of the enterprise	a6a(size)	Size: small if number of employees is from 5 to 19 employees; middle: 20-99 employees; large: more than 100 employees
Using computers	ecao6	% of establishment's workforce that regularly use computers in their jobs

Table B1. Variables description – Continued.

Innovations(new product or service)	ecao1	Has this establishment introduced new products or services in the last 3 years?
Government subsidies	ecaq53	Over the last 3 years, has this establishment received any government subsidies?
Share of skilled labor	l4a/l1	Number of fulltime employees who were skilled productive workers at the end of last fiscal year / Number of permanent, full-time employees of this firm at the end of last fiscal year
Foreign technology	e6	Do you use technology licensed from a foreign-owned company?
Main market: international	e1	Main market in which you sold your main product or service in last fiscal year
Investments	n5a n5b	Total annual expenditure for purchases of equipment in last fiscal year; Total annual expenditure for purchases of land and buildings in last fiscal year
Control variables		
Industry	a4b	Industry screener sector
Country	a1	Country code
Year of survey	year	Year of survey

APPENDIX C

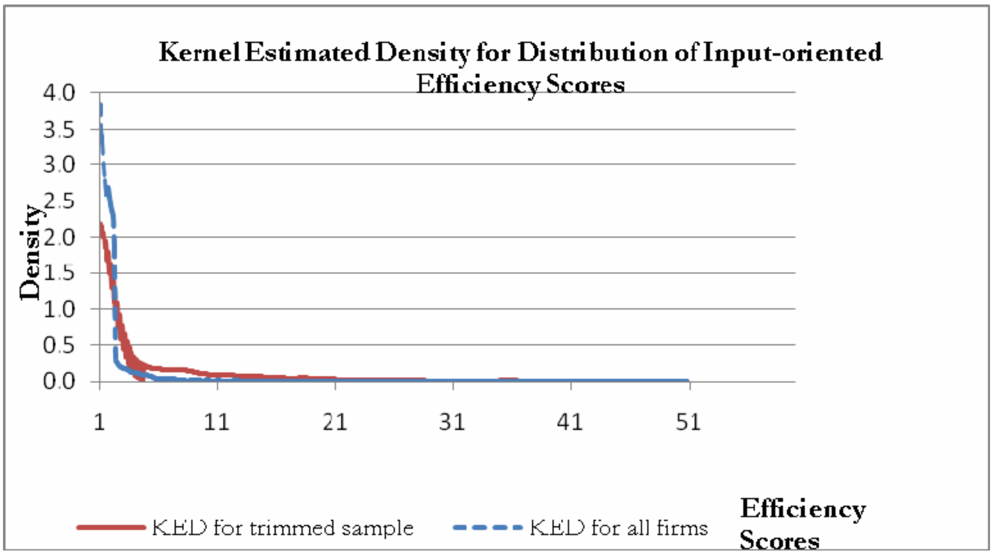

Figure C1. KED of input-oriented efficiency scores.

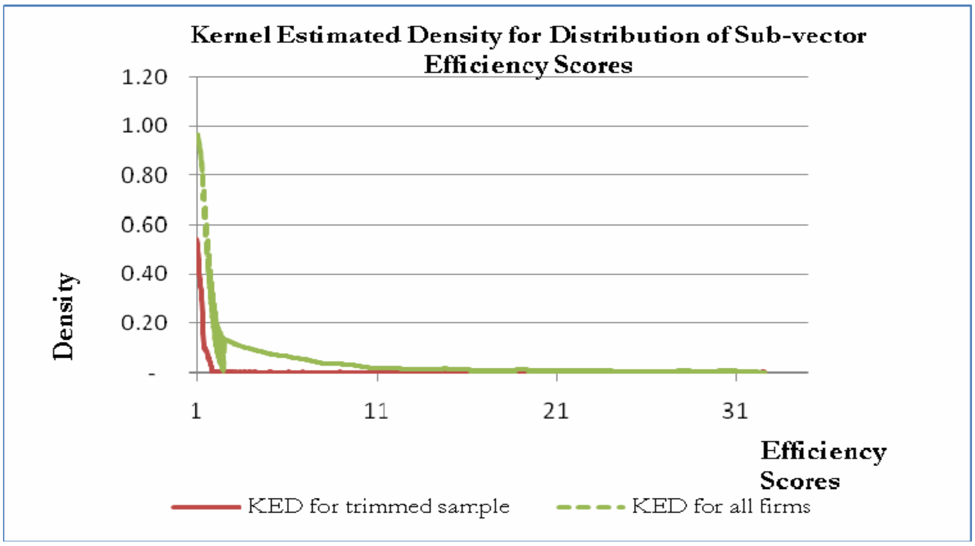

Figure C2. KED of energy-oriented efficiency scores.

APPENDIX D

Table D1. Results of truncated regression analysis for input-oriented efficiency.

Explanatory variables	Coef.	Bounds of confidence intervals (estimated via bootstrap) Lower 1%	Upper 1%	**Lower 5%**	**Upper 5%**	Lower 10%	Upper 10%
Share of foreign	0.005	0.005	0.005	**0.005**	**0.005**	0.005	0.005
Share of state	0.056	0.055	0.057	**0.055**	**0.056**	0.056	0.056
Log(total annual sales)	0.016	0.016	0.016	**0.016**	**0.016**	0.016	0.016
Log(annual investments)	-1.165	-1.187	-1.162	**-1.173**	**-1.164**	-1.169	-1.165
Share of labor using computers	-0.005	-0.005	-0.005	**-0.005**	**-0.005**	-0.005	-0.005
Skilled labor (%)	-10.205	-10.388	-10.136	**-10.271**	**-10.191**	-10.215	-10.205
Size (dummy for medium)	0.100	0.098	0.100	**0.099**	**0.100**	0.100	0.100
Size (dummy for large)	4.848	4.765	5.070	**4.804**	**4.851**	4.845	4.848
Dummy for new product	-0.334	-0.338	-0.332	**-0.336**	**-0.334**	-0.335	-0.334
Dummy for subsidy	-0.442	-0.448	-0.440	**-0.445**	**-0.442**	-0.444	-0.442
Main market: international (dummy)	-0.349	-0.353	-0.346	**-0.351**	**-0.349**	-0.349	-0.349
Foreign technology	-0.003	-0.003	-0.003	**-0.003**	**-0.003**	-0.003	-0.003
Survey_year_2008	-0.410	-0.412	-0.405	**-0.410**	**-0.407**	-0.410	-0.408
Survey_year_2009	n/a	n/a	n/a	**n/a**	**n/a**	n/a	n/a
Food	-0.027	-0.027	-0.026	**-0.026**	**-0.026**	-0.027	-0.026
Textile	-2.401	-2.419	-2.380	**-2.405**	**-2.388**	-2.401	-2.401
Garments	0.119	0.118	0.120	**0.118**	**0.120**	0.119	0.119
Chemicals	-0.170	-0.174	-0.168	**-0.170**	**-0.169**	-0.170	-0.169
Plastics and rubber	-4.390	-4.666	-4.390	**-4.581**	**-4.390**	-4.476	-4.390
Non met. min. prod.	-1.999	-1.999	-1.954	**-1.999**	**-1.978**	-1.999	-1.986
Basic metals	n/a	n/a	n/a	**n/a**	**n/a**	n/a	n/a
Fabricated met.products	0.094	0.093	0.094	**0.093**	**0.094**	0.093	0.094
Machinery and equipment	4.820	4.746	4.964	**4.775**	**4.821**	4.811	4.820
Electronics	-1.278	-1.281	-1.260	**-1.279**	**-1.267**	-1.278	-1.271
# observations	1812						
σ_{ε}^{2}	13.533	13.283	13.534	**13.404**	**13.533**	13.463	13.533

Notes: (i) Estimation according to the Algorithm 1of Simar and Wilson (2007). Number of bootstrap replications: 2000. (ii) n/a for variables excluded due to collinearity. (iii) Country dummies (included but not reported) are significant at 5% level.

Table D2. Results of truncated regression for energy-oriented efficiency.

Explanatory variables	Coef.	Bounds of confidence intervals (estimated via bootstrap) Lower 1%	Upper 1%	Lower 5%	Upper 5%	Lower 10%	Upper 10%
Share of foreign	0.046	0.045	0.046	**0.046**	**0.046**	0.046	0.046
Share of state	0.009	0.009	0.009	**0.009**	**0.009**	0.009	0.009
Log(total annual sales)	1.413	1.413	1.413	**1.413**	**1.413**	1.413	1.413
Log(annual investment)	-4.237	-4.238	-4.237	**-4.237**	**-4.237**	-4.237	-4.237
Share of labor using computers	0.004	0.004	0.004	**0.004**	**0.004**	0.004	0.004
Skilled labor (%)	0.795	0.795	0.796	**0.795**	**0.795**	0.795	0.795
Size (dummy for medium)	0.027	0.027	0.027	**0.027**	**0.027**	0.027	0.027
Size (dummy for large)	0.594	0.594	0.594	**0.594**	**0.594**	0.594	0.594
Dummy for new product	-0.644	-0.644	-0.644	**-0.644**	**-0.644**	-0.644	-0.644
Dummy for subsidy	-0.052	-0.052	-0.052	**-0.052**	**-0.052**	-0.052	-0.052
Main market: international (dummy)	0.002	0.002	0.002	**0.002**	**0.002**	0.002	0.002
Dummy for foreign technology	0.075	0.075	0.075	**0.075**	**0.075**	0.075	0.075
Survey_year_2008	-44.978	-44.985	-43.845	**-44.978**	**-44.978**	-44.978	-44.978
Survey_year_2009	-62.506	-62.507	-59.381	**-62.492**	**-59.381**	-59.381	-59.381
Food	17.314	16.872	17.316	**17.314**	**17.314**	17.314	17.314
Textile	-1.224	-1.224	-1.223	**-1.224**	**-1.224**	-1.224	-1.224
Garments	-0.481	-0.481	-0.481	**-0.481**	**-0.481**	-0.481	-0.481
Chemicals	-0.116	-0.116	-0.116	**-0.116**	**-0.116**	-0.116	-0.116
Plastics and rubber	0.499	0.499	0.499	**0.499**	**0.499**	0.499	0.499
Non metallic min. prod.	0.136	0.136	0.136	**0.136**	**0.136**	0.136	0.136
Basic metals	10.263	10.253	10.263	**10.263**	**10.263**	10.263	10.263
Fabricated metal products	-0.155	-0.155	-0.154	**-0.155**	**-0.155**	-0.155	-0.155
Machinery and equipment	-3.268	-3.268	-3.266	**-3.268**	**-3.268**	-3.268	-3.268
Electronics	0.238	0.238	0.238	**0.238**	**0.238**	0.238	0.238
# observations	1740						
σ_{ε}^{2}	19.568	19.568	19.569	**19.568**	**19.568**	19.568	19.568

Note: (i) Estimation according to the Algorithm 1of Simar and Wilson (2007). Number of bootstrap replications: 2000. (ii) Country dummies (included but not reported) are significant at 5% level.