Estimating Firm Efficiency in Estonia: A Stochastic Frontier Approach

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Abstract

In this paper we explore the relation between the dynamics of firm efficiency, firm ownership structure and market structure. We estimate firm level efficiency using a panel of Estonian firms over the period 1993-1999 and estimate production functions employing the stochastic frontier, FRONTIER 4.1 (Coelli, 1994), where firm level efficiency and its determinants are estimated simultaneously. The estimated production functions are fitted to cross-sections as well as both balanced and unbalanced panels. The results show that efficiency increased over time across all ownership groups. Across different ownership structures, foreign owned firms have been the most efficient over time with state and employee-owned firms alternating as the second best performing group of firms.

Key words: Stochastic Frontier, Ownership Structure, Efficiency, Panel Data.

JEL classification: C23, C87, D21, P20.

1. INTRODUCTION

It is widely acknowledged that centrally planed economies were highly inefficient. These inefficiencies stemmed from the fact that firms were not maximizing profits as their goals were determined by state planners, who were supposedly maximizing social welfare. In addition, consumer preferences were not taken into account and production was characterized by use of outdated capital and technology. Furthermore, state enterprises were protected from bankruptcy from soft-budget constraints and lack of competition. Under these circumstances restructuring was considered vital for the survival of these firms in a market-oriented economy and accordingly privatization was considered the means to implement and accelerate restructuring.

The literature on firm performance in transition economies points out that despite of the methods of privatization CEEC and FSU (Central and Eastern European Countries and Former Soviet Union countries) followed, many of them tended to favor insider ownership (Estrin and Wright, 1999; Filatochev et al., 1996; Smith et al., 1997; Blanchard and Aghion, 1996). In contrast to Ben-Avner et al., (1998), who argue that task complexity at work has motivated firms in U.S. to develop procedures for involving employees in decision making, in transition economies favoring insider ownership was mainly the result of political power. By giving control to insiders, whose interests (mainly employment) aligned with theirs, politicians expected increased number of votes in election. Nevertheless, in between employees and managers, managers are harder to convince to incur extra spending on excess labor. For this to happen politicians have to make actual transfers of cash flow to managers. Therefore, privatization is likely to lead to restructuring by raising the cost of politicians to influence shareholders (Boycko et al., 1996). As mentioned in Blanchard and Aghion (1996), an argument in favor to privatization by insiders would be that both control and property rights increase their incentives to take the right decisions. Nevertheless, the evidence (especially the example of Russia) has shown that insiders are not able to restructure because of lack of capital and expertise. Therefore, privatization to outsiders would make restructuring possible (Aghion and Blanchard, 1996,1998). Blanchard and Aghion's (1996) model predicts that insider privatization can lead to an excess resale price and thereby block outside privatization. In addition, by giving a large number of shares to managers does not seem to increase the likelihood of resale. However, Aghion and Blanchard (1998) conclude that resale to outsiders could happen if since at the beginning insider owners are set as to avoid collusion of workers in resale, and shares are traded anonymously and registered outside the firm.

The empirical literature investigates the importance of privatization in two streams of studies. The first stream compares the pre- and post-privatization firm performance[1]. For instance, when comparing the pre- and post-privatization performance of firms in 28 industrialized countries, Megginson and D'Souza (1999) find evidence of increase in profitability, operating efficiency and output. Such findings support the view that privatization improves performance. In contrast, the second stream of studies compares performance between different ownership structures. The expectations of researchers in this stream of literature are such that state-owned firms would perform worse than the other ownership structures and therefore privatization would improve firm performance[2]. For instance, Smith et al., (1997) compare the performance of employee and foreign owned firms for a sample of Slovenian firms and find that foreign ownership increases firm performance more than employee ownership. In addition, Pohl et al., (1997) investigate the impact of restructuring in seven Central and Eastern European countries. They find that fast privatization (regardless of the method) is important for restructuring and that the longer the privatization time the higher the firm's productivity. Furthermore, for the sample of Czech firms, they found that firms with concentrated ownership had restructured more than firms with dispersed ownership. Frydman et al., (1999) compare the performance of state and privatized firms in three transition economies Czech Republic, Hungary and Poland for the period 1990-1993. They find that privatization does not improve the performance of the insider owned firms, however, it improves the performance of firms owned by outsiders, with domestic outsiders performing slightly better than foreign outsiders. Thereby, privatization "works" only if the firm is controlled by outsiders. The studies of Earl (1998) and Estrin and Earl (1998), confirm Frydman's et al. (1999) conclusions, as they find that outsider ownership is significantly associated with improved labor productivity[3] in Russian firms.

Finally, Djankov and Murrell (2002) in a literature review of the studies on privatization in transition economies conclude that in general privatization is inclined to improve firm performance. In most of the cases privatized firms perform better than state owned firms and that concentrated ownership is beneficial for firm performance. Furthermore,

[1]For more in this issue read Megginson et al (1994) and Lopez-de-Silianes and La Porta (1997).

[2] The literature on firm performance and privatization is overwhelming, therefore, for an excellent review of this literature, and the one that focuses on transition economies read Megginson and Netter (2001) and Djankov and Murrell (2002).

[3] For more evidence on the impact of privatization on firm performance in Russia read Djankov (1999a, 199b) and Brown and Earl (1999, 2001).

the central and eastern European countries experienced a larger positive impact of privatization than the CIS countries.

Nevertheless, it is imperative mentioning that the literature on firm performance and privatization has faced different estimation challenges. As mentioned in Bevan et al., (1999), Filer and Hanosek (2001) and Djankov and Murrell (2002) problems related to differences in accounting standards undermine the credibility of performance variables most of the times. Therefore, researchers have employed as many dependant variables as possible in the attempt to reach robust conclusions on the impact of privatization on firm performance. Furthermore, data samples have been small and not representative and the endogeneity of ownership structure has been a problem in capturing the true effect of ownership structure on performance. Furthermore, isolating the effect of privatization in transition economies is even more difficult as it was associated with other major political and economical changes.

The goal of this paper is to analyze the effect of different ownership structures as well as other firm level characteristics on firm efficiency. To this end, we will attempt to avoid most of the above problems. First, instead of estimating the impact of privatization on firm performance and making inferences about firm efficiency, we will investigate the impact of privatization, directly, on firm efficiency, using the stochastic frontier approach. Therefore, we will be able to estimate the scale of firm efficiency and investigate what are the factors that affect (in)efficiency. The data we employ is extracted from a representative sample of 666 Estonian firms, over the period 1993-1999. We estimate production functions running the stochastic frontier and correcting for the endogeneity of ownership structure.

2. Data Section

The data used in this analysis contains yearly information on Estonian firms for the period 1993-1999. This data has been obtained from the Estonian Statistical Agency (ESA) and, in broad terms, consists of ownership and financial information. The ownership information is provided by a special ownership survey run by ESA sent to non-fully state owned firms, i.e. firms that have been fully or partially privatized. This information is then augmented with that of the fully state owned firms known as such in a given year. Financial and wage data comes from firm's financial statements (balance sheet and income statement). The data below is extracted from company records of 666 Estonian firms.

Table 1, shows the distribution of firms over time according to majority ownership. As seen we classify firms as majority foreign, domestic, employee, manager, and state owned.

Furthermore, the data set used in the estimation consists of 1393 observations and includes all firms with more than 10 employees. The different number of firms in every year is caused by exit of firms over time. Hence, the panel is unbalanced.

From the distribution of firms according to their majority ownership structure, one can see that the number of firms owned by foreign owners has been increasing over time. However, domestic outsider-owned firms seem to dominate over foreign owned, employee and managerial owned firms. In addition, the number of state-owned firms has been declining almost over all of the period.

A common problem with data over time is that for a given year data is expressed in current prices. This makes it important to avoid biases that might arise due to inflation. With 1993 as the base year, all variables are deflated to 1993 prices using the appropriate three digit PPI deflators.

In what follows, Tables 2, provides the mean and standard deviations of main variables and Table 3 provides variable definitions. Regarding variable definitions, we would like to clarify that in constructing the dummy on the soft budget constraints (SBC) we follow Schaffer (1998). As in Schaffer (1998) a firm has SBC if it is loss making, economically distressed, and is receiving net financing either as subsidies or in form of lending and increases in debt over interest costs. SBC is then constructed as follows:

a) Net Financing= [Debt(t)- Debt(t-1)-Interest Cost(t)]/Fixed Assets

b) SBC=1 if Net Financing>0 & EBITD<0, zero otherwise.

Where, EBITD is earnings before interests, profit taxes and depreciation.

Finally, although our data contains observations for years 1993-1999, we use lags to construct the predictions on ownership dummies and the dummy of the soft budget constraint. Therefore, our final empirical analysis (the frontier estimation) is performed only for years 1994-1999.

A final remark regarding the data is the consistency checks performed to eliminate potential outliers, as the estimation of the stochastic frontier is very sensitive to them (outliers push the frontier up for other firms). Therefore, we control for outliers checking firms' capital, employment, salaries and value added. This consistency check reveals that only two firms are outliers. Consequently, they were dropped from the sample.

3. Determinants of Firm Level Efficiency.

The theoretical and empirical literature on firm performance and privatization identifies competition, firm ownership structure, soft budget constraints, firm trade orientation and firm level of investments and the quality of labor, among others, as determinants of firm performance and consequently firm efficiency (Djankov and Murrell, 2002; Walsh and Whelan, 2001; Brown and Earl, 2001; Frydman et al., 1999).

Competition: is an important factor for efficiency as it induces firms to use efficiently their inputs or pushes inefficient firms out of the market. It is introduced from both domestic and foreign firms.

Ownership structure: For reasons related to access to capital markets, mitigation of agency problems and alignment with the profit maximization goal of the firm, outsider owned firms are expected to be more efficient than insider owned firms. Nevertheless, the literature also refers to cases when state owned enterprises have been found to perform no worse than other ownership structures.

Soft budget constraints: is detrimental for firm efficiency, because by bailing out firms, especially large enterprises, state distorts managerial incentives and erodes the effect of competitive pressure.

Investment in fixed capital: Investment is important in substituting obsolete for advanced technology. In return, this will contribute to increase in productivity and thereby efficiency.

Trade orientation: It is expected that firms that produce mainly for export are under the pressure of international competition, hence will utilize resources more efficiently. Furthermore, such firms may have the possibility of getting to know about the advanced technology of their knowledgeable buyers or competitors.

Average labor cost: proxies for labor quality. The higher the level of labor quality, the more efficient the usage of existing technology and the absorption of new technology.

In addition to these determinants, in this paper we consider the effect of other *firm characteristics* such as firm size and firm's sector affiliation.

4. The Estimation of the Stochastic Frontier.

The appropriate functional form of the stochastic frontier will be determined by testing the adequacy of the Cobb-Douglas relative to the less restrictive translog form.

The frontier will be defined as in Batese , Coelli and Rao (1998):

$\ln y_{it} = \ln f(x_{it}; t, \beta) + v_{it} - u_{it}$ (1)

x_{it} - is vector of input quantities

t – is a time trend

v_{it} – white noise, assumed to be normally and identically distributed $N(0, \sigma_v^2)$

u_{it} – is the measure of inefficiency and is half normally distributed, $N(\mu_{it}, \sigma_u^2)$. Mean inefficiencies μ_{it} for each firm are explained by the Z variables.

$\mu_{it} = a_0 + a_1Z_1 + a_2Z_2 + a_3Z_3 + \ldots\ldots\ldots\ldots + a_kZ_k$ (2)

where a_i are parameters to be estimated.

To estimate the model they use the parametrization in Battese and Corra (1977) replacing σ_u^2 and σ_v^2 with $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$

(3)

This model is then estimated with MLE, and its log-likelihood function can be found in Battese and Coelli (1993).

We estimate (1) and (2) simultaneously using Frontier 4.1 (Coelli, 1994). In addition to determining the production function that best fits the data, we also test whether the inefficiency effects are not necessary in the model (a_j=0), i.e. that OLS is an adequate representation of the data versus the stochastic frontier. The null hypothesis then is γ=0 (inefficiency effects are not present in the model). γ takes values between 0 and 1 and large values of γ imply that the inefficiency function is an important part of the production function.

Technical efficiencies are retrieved from: $TE_{it} = \exp(-u_{it})$ (4)

Thus technical efficiency is inversely related to the inefficiency effect measured in (2) and ranges from zero to one.

Finally, as explained in the previous session, variables employed to explain inefficiencies in equation (2) are:

Z_1- probabilities of firms being in a given ownership group at a given point in time.

Z_2 – Firm Size

Z_3 – Share of firm level exports to sales.

Z_4 – Dummy for Soft Budged Constraints

Z_5 – Competition (measured with the herfindahl index at the 3 digit isic)

Z_6 – Dynamic Time of Privatization

Z_7 – The share of firm level investment in new machinery and equipment to sales.

Z_8 – Average labor cost (as a proxy for labor quality, i.e. the higher the labor cost the higher the labor quality of the firm)

Z_9 – Dummy for High Tech industries

Z_{10}– Time trend and industry dummies

5. The Instruments for the Endogeneity of Ownership Structure.

The possible endogeneity of ownership structure is a very well discussed issue in the literature of firm performance and restructuring. Demetz and Lehn (1985) are among the first to acknowledge the severity of such problem and the importance of correcting for it. In spite of the fact that their work was based on a sample of U.S. corporations owned almost entirely from outsiders, it set the grounds for an ongoing debate of this issue in transition analysis (Marcinein and Wijnbergen, 1997; Smith et al., 1997; Earle and Estrin, 1997, 1998; Classesns et al., 1997; Frydman et. al., 1999, etc). The possible endogeneity of ownership structure steams from the fact that during the privatization process in transition economies, the state offered for privatization mainly those firms that performed well during the pre-privatization period. Hence performance measures also determine ownership structure. Not correcting for this kind of bias leads to upward biased estimates of ownership structure on performance (Greene, 1995). The literature on firm performance and restructuring has been correcting for endogeneity with two procedures. Given the argument that the best firms were offered for privatization, the sample of data is biased and hence a Heckman two-step procedure is employed to correct for it (Marcinein and Wijnbergen, 1997). With this procedure researchers have corrected for the sample selection bias steaming from privatization in general. The second procedure corrects for the possible endogeneity of privatization to particular types of owners. As such, it instruments the variables of ownership structure with its predicted values obtained from a two-step procedure. In the first step, the predicted values of ownership structure are obtained using a treatment procedure, a two-limit Tobit model, instrumental variables or simply a logit model. In the second step the predicted values of ownership structure are used instead of the ownership variable (Smith et al., 1997, Frydman et. al., 1999; Walsh and Whelan, 2001). The study of Frydman et al. (1999), which is the first to control for different types of biases such as ownership group and firm specific effects, uses previous period performance variables to account for the endogeneity of ownership structure with the treatment procedure.

In this paper we will account for the endogeneity of ownership by instrumenting it with variables drawn from the determinants of ownership structure. In finding good instruments for the ownership structure we rely on the literature on the determinants of ownership structure (Jones and Mygind, 1999 and Earl and Estrin, 1997).

5.1 Some theoretical arguments on the possible determinants of ownership structure.

The theoretical literature (Aghion and Blanchard, 1998 and Boycko et al., 1996) argues that restructuring requires outsider ownership, which is able to bring the expertise and the amount of capital necessary for restructuring. Moreover, firms with high *capital intensity* would require higher per worker capital financing. Therefore, outsiders and large foreign firms would be more likely to invest in such firms relative to insiders, as they possess the financial means Ben-Ner et al., (1998). Furthermore, *firm characteristics* can make some firms more attractive than others (Earle and Estrin, 1997). Because *large firms* are of strategic importance to state they tend to remain state owned even after privatization. In addition, because of wealth limitations and risk averseness outsiders are more likely to invest in large firms then insiders.

Another determinant of firm characteristics is *the quality of the firm* (Earl and Estrin, 1997). The main hypothesis raised in the literature is that the better firms were given out for privatization. Hence, variables of firm performance such as *labor productivity* and *profit* are important for determinants of ownership structure.

Nevertheless, not all firms are interested in profit maximizing or higher labor productivity. For instance, employee and state owned firms have as goals the maximization of employment. Therefore they are expected to perform worse than other ownership structures (Aghion and Blanchard, 1998; Frydman and Hessel, 1999).

Moreover, differences in productivity across industries and regions may affect the ownership structure and its potential changes.

Following this discussion, we identify capital intensity, firm size, firm quality (labor productivity), previous year ownership structure and industry dummies as possible instruments of ownership structure.

5.2. Accounting for Ownership Endogeneity.

Given the previous discussion, in this section we will proceed with correcting for ownership endogeneity by estimating the probabilities that a given firm belongs to one of the

five ownership structures (state, insider (manager, employee), outsider and foreign) and substituting these probabilities for the ownership dummies. These probabilities will be estimated using the logit models, relying on the aforementioned determinants of ownership structure.

The empirical analysis is similar to that of Jones and Mygind (1999). To instrument the ownership structure in a given year, we will use its previous year determinants. Consequently, our instruments are exogenous and as explained in the previous section correlated with the ownership structure. These instruments consist of a vector of firm characteristics and ownership structure. The vector of ownership structure is a dummy variable for each of the majority structures of the previous period, included to account for possible changes in ownership structure. As argued in Ben-Ner et al. (1998) and Aghion and Blanchard (1996), because of wealth limitations and risk aversion and lack of expertise, it is more likely that the ownership change will be from employee owned to outsider owned firm. Therefore, the previous period respective ownership dummy will be included in the analysis to account for possible changes in ownership structure.

The vector of firm characteristics includes firm size, capital intensity and proxies for firm quality. Firm size is proxied with the logarithm of the average number of employees of the previous period. In addition, the logarithm of capital intensity (capital to labor ratio) is included to account for differences in capital intensity across firms that can influence the ownership structure of the firm. Furthermore, we include as proxies for firm quality the logarithm of sales to employee. To capture the importance of privatization on the ownership structure we include a dummy variable that takes value 1 for firms privatized during and after 1993 and zero otherwise. Finally, the industry dummies are included to account for differences in ownership dynamics across sectors.

6. Estimation Results

The estimation of the frontier requires the specification of the production function. Accordingly, instead of assuming an ad hoc functional form, we test for the appropriate specification that bests fits the data. Consequently, the first test reported in Table 4 is the selection of the appropriate production function in the frontier estimation. The null hypothesis

is that Cobb-Douglas is the appropriate functional form versus Translog. The likelihood ratio[4] (LR) test suggests that the Translog function is accepted in all cases, except for years 1994 and 1995, for which the Cobb-Douglas function better represents the data. The second part of Table 4 presents the results of LR test on the relevance of using a stochastic frontier approach versus the usual mean response function (OLS). The test we perform is that $\gamma = a_j = 0$, i.e. neither the constant nor the (in)efficiency effects are at all necessary in the model. In other words, we do not need to run SFA when the mean response function adequately represents the data. For this test, the test statistics has a mixed chi-squared distribution. The results of this test show that in all cases, the (in)efficiency effects are required in the model. This implies, that for a transition country like Estonia (in)efficiencies have been persistent during the period 1994-1999.

Given that the Translog function was accepted as the appropriate specification in most of the cases, we present estimation result using this functional form. The stochastic frontier for this production function is, then, estimated using the FRONTIER 4.1 (Coelli, 1994), where the (in)efficiency parameters (Z_i) are specified as in section 4. Furthermore, the Translog function was fitted to cross-sections and both balanced and unbalanced panel to account for inter temporal changes.

The first part of table 5 presents the estimates of the production function. From point estimates of table 5, respective elasticities of capital and labor were calculated, as shown in table 6. The results show that in general labor is more elastic than capital, except for years 1995 and 1999. In addition, the specification of the production function includes the Herfindahl index, to measure the impact of competition on firm level productivity. The results show that whenever significant, more competition results in higher productivity.

The second part of table 5 presents the estimates of the (in)efficiency function for each year and for both balanced and unbalanced panel. The results reveal that ownership structure is a significant determinant of firm level (in)efficiency. Over time, coefficients of ownership structures display substantial variation in magnitude and changes in sign. However, the results from both unbalanced and balanced panel show that only foreign and managerial-owned firms are on average more efficient than state-owned firms (the control group). Other variables that significantly affect efficiency are firm size, Herfindahl index, soft budget constraints, and average labor cost (labor quality). Among them, only the effect of the latter two variables is

[4] Likelihood ratio tests needed to construct the test statistics are estimated from the Frontier 4.1 program as part of the frontier results. For a better understanding of the tests read Coelli, Battese and Rao (1998).

robust across all specifications. More specifically, the effect of soft budget constraints is positive and significant, with the exception of the coefficient of 1996 that is insignificant, while the effect of average labor cost is negative and significant across all specifications. These results suggest that, as expected, the availability of easy financing (soft budget constraints) is detrimental to firm level efficiency, while the availability of qualified workers, at firm level, results in higher efficiency.

Turning to the effect of firm size and competition variable, we see that coefficients alternate in sign and significance across specifications even when considering only panel estimates. Focusing only on the panel results, we see that both firm size and competition (Herfindahl index) are positively associated with level of efficiency. That is large firms and those operating in more competitive environments display higher levels of efficiency.

6. The Distribution of Firm Level Efficiency over Time and across Ownership Groups.

In this section we will briefly discuss the distributional patterns of firm level efficiency over time. As already noticed in section 5, mean efficiency is low, however increasing over time. Nevertheless, we are interested in distinguishing between firms that operate at low levels of efficiency from those that operate at higher levels of efficiency. After all, as discussed firm level efficiency is determined from different firm level characteristic, as such we expect some firms to be more efficient that the others. Accordingly, we create 5 groups of firm level efficiency. The first group, includes all those firms that operate in between 0-20 % level of efficiency; the second group includes firms that operate between 20-40 % level of efficiency and the other three groups include firms that operate between 40-60%, 60-80% and 80-100% level of efficiency. Graph 1 represents the distribution of firms according to this grouping over time.

This graph reveals that during 1994 almost 80 % of the firms operate at very low levels of efficiency. This result is expected as early transition was characterized by highly inefficient firms, who inherited from the centralized market economy outdated capital, lack of advanced technology, expertise and resources necessary to survive in the open market economy. Furthermore, we see that inefficiency drops dramatically from 1994 to 1998. On the other hand, a very interesting finding is that the percentage of firms belonging to the last three efficiency groups (40-60, 60-80 and 80-100%) has increased over time. At this point we can speculate that reasons related to privatization, such as restructuring and the introduction to market competition might have played an important role to increasing firm efficiency.

To further corroborate this finding, we investigate the dynamics of efficiency across different ownership groups and over time (Graph 2). From this graph we can see that while foreign firms are most efficient over the whole period, there is no other group that persistently dominates the rest of ownership structures. However, what emerges from the picture is that state owned firms and employee owned firms alternate as the second best. This finding is consistent with the hypothesis that employee ownership is expected to produce more interest alignment and more involvement of employees and, in turn, better organizational performance compared to outsider and state owned firms. Furthermore, our results are in line with those obtained by Jones and Mygind (2000), who find that insider-owned firms are superior compared to other domestic ownership structures.

Finally, this graph, likewise graph 2, reveals that no matter the ownership structure, efficiency has increased over time.

7. CONCLUSIONS

In this paper we estimate firm level efficiency using a panel data for Estonia. The analysis was performed for the manufacturing sector only, employing the Frontier 4.1 (Coelli, 1994) program. Furthermore, we perform two tests: first, for the appropriate specification of production function that best represents the data and second whether we, at all, need the stochastic production function to estimate firm efficiency. The results of these tests reveal that in almost all cases the Translog function best represented the data and that in(efficiency) effects should be included in the model when estimating efficiency. That is, the stochastic frontier is a better estimation procedure versus the OLS.

The estimation of the stochastic frontier, reveals that ownership structure is a significant determinant of firm level (in)efficiency. The results from both unbalanced and balanced panel show that both foreign and managerial-owned firms are on average more efficient than state-owned firms (the control group). Differently, being state or managerial-owned firm increases firm level efficiency compared to state owned firms Furthermore, as expected, the availability of easy financing (soft budget constraints) is detrimental to firm level efficiency, while the availability of qualified workers, improves firm level efficiency. In addition, large firms and those operating in more competitive environments display higher levels of efficiency.

Finally, the dynamics of firm efficiency across different ownership structures shows that efficiency has increased over time across all ownership groups. Furthermore, foreign

owned firms have been the most efficient over time with state and employee-owned firms alternating as the second best performing group of firms.

Appendix

Table 1. The distribution of firms over time according to majority ownership.

Year	No Answer	No Majority	Domestic	Employee	Foreign	Manager	State	Total
94	35	0	55	25	28	25	80	248
95	0	7	55	25	29	26	124	266
96	1	5	73	20	41	36	83	259
97	5	5	68	11	41	35	71	236
98	3	5	59	9	35	33	57	201
99	12	5	68	14	46	37	1	183
Total	56	27	378	104	220	192	416	1393

Note: Observations belonging to the "No Answer" and "No Majority" category are not included when estimating the frontier, as they do not fall under the majority ownership category.

Table 2: Mean and Standard Deviations of main variables.

Variable	Obs.	Mean	Std. Dev.
Net Sales	1393	27273.9	63254.1
Capital	1393	9634.6	24534.46
Labor	1392	172.033	288.6868
Avg. Labor Cost	1392	27.3953	17.51175
Value Added	1393	6486.52	12045.98
Investment/Y	1392	0.0211	0.361212
Export/Y	1393	0.3268	0.326862
Dummy SBC	1317	0.10478	0.306391
Dynamic Time Privatization	1393	4.03015	3.136815
Time Trend	1393	3.305097	1.655567

Table 3: Variable Definition

Variables	Definition
Value Addded	The dependant variable is constructed as the sum of Net Profit, Depreciation and Labor Cost (Wage Salary +Social Security +interest costs). Expressed in thousands of kroons.
Employment	Firm's average number of employees per year.
Capital	Capital is calculated as the average of fixed assets at the beginning and end of year. Expressed in thousands of kroons.
Herfindahl (3 digit)	Used to capture monopoly power $\text{Herfindahl}_j = \sum_i \left(\frac{Sale_i}{Sale_j} \right)^2$ j-industry, i -firm Constructed at the three digit industry classification.
Majority Ownership	This is a dummy equal to 1 if one of the ownership categories owns at least more than 50% of firm's equity.
Firm' Debt (used to construct SBC dummy)	Is constructed as the sum of Current Debt and Current Payables. Expressed in thousands of kroons.
Net Financing (used to construct SBC dummy)	Constructed as [Debt(t)- Debt(t-1)-Interest Cost(t)]/Fixed Assets
EBITD (used to construct SBC dummy)	Is the sum of Gross Profit and Depreciation. Expressed in thousands of kroons.
Dummy Soft Budget Constraint	Equals 1 if Net financing>0 & EBITD<0, zero otherwise.
Average Labor Cost	Used to proxy labor quality. Expressed in thousands of kroons.
Dynamic Time Privatization	Takes values from 1 to 12 if firms have been privatized between 1988-1999.
Sales	Net sales are expressed in thousands of kroons. Available at firm level
Investment/Sales	The share of expenditure on new machinery and equipment to net sales of the firm. Used to account for investment in new technology.
Export/Sales	The share of firm's export to net sales.
*Dummy High Tech Industries	This is a dummy equal to 1 if the firm belongs to a high tech industry. Such industries are: 1) Manufacture of chemicals and chemical products. 2) Manufacture of electrical and optical equipment[4]
Firm Size	The logarithm of firm level employment.
d_t	Time Trend: 1) Included at the production function to account for productivity shocks. 2) Also included at the inefficiency function to account for temporal changes in technical efficiency.
d_j	Industry dummy, constructed on a two-digit level industry classification

*According to the Estonian Technology Agency 2002 these industries have the highest innovation expenditure intensity.

All data has been deflated before variable construction.

Table 4: Test results on the choice of functional form and the adequacy of Stochastic Frontier[6]

Manufacturing								
Test on the choice of functional form: Cobb-Douglas vs. Translog. H_0: Cobb-Douglas is the appropriate functional form. Test Statistic ($\chi^2_{3,0.95}$)= 7.82 (Panel $\chi^2_{6,0.95}$ =12.59)								
	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**Panel**	**Bal. Panel**
Test Statistic (LR)	1.04	5.28	69.8	53.44	32.5	13.26	68.3	44.4
Decision	Accept	Accept	Reject	Reject	Reject	Reject	Reject	Reject
[7]Test of the adequacy of Stochastic Frontier. H_0: $\gamma = a_k = 0$ (OLS is the appropriate estimation) ($\chi^2_{k,0.95}$)= 38.301 (panel=39.531)								
γ **value**	0.13	0.67	0.66	0.68	0.94	0.99	0.80	0.99
Test stat (LR)	262.1	180.9	69.70	198.2	190.6	221.6	752.2	665.9
Result	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
Decision	Front	Front	Front	Front	Front	Front	Front	Front

[6] The likelihood ratio test statistic is $\lambda = -2\{\log(likelihood(H_0)) - \log(likelihood(H_1))\}$ has a χ_k^2 distribution where k is the number of parameters assumed to be zero in the null hypothesis, in our case k=6.

[7] The test statistics has a mixed Chi2 distribution, critical values taken from Kodde and Palm (1986).

Table5: Frontier Estimation of the Translog Production Function.

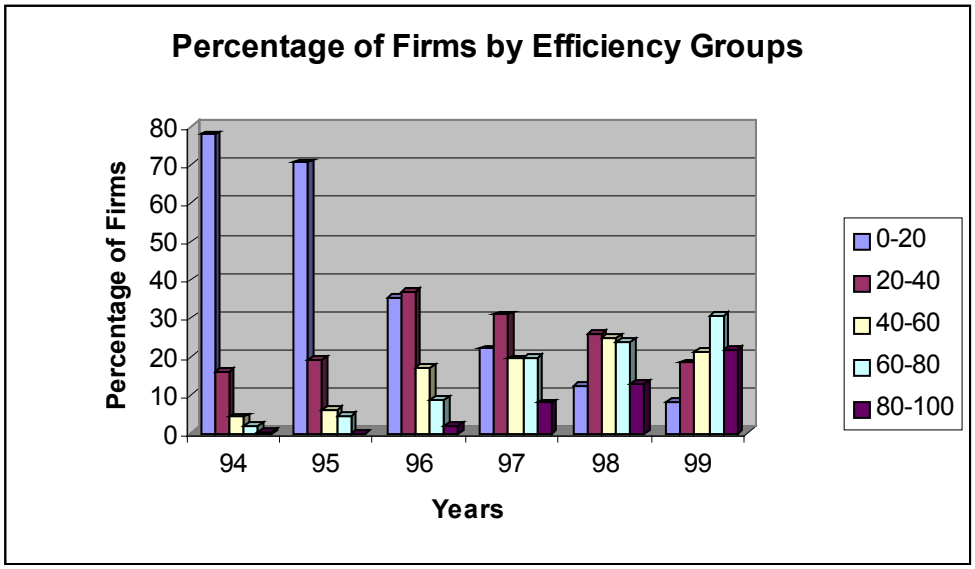
Production	**1994 TR**	**1995 TR**	**1996 TR**	**1997 TR**	**1998 TR**	**1999 TR**	**Panel TR**	**Balanced Panel TR**
Constant	3.91* (9.98)	4.16* (5.82)	2.30* (6.2)	4.47* (6.5)	4.29* (6.55)	1.98* (9.25)	7.97* (11.5)	3.96* (11.6)
LnK	0.11*** (1.30)	-0.16*** (-1.33)	0.32* (4.03)	0.048 (0.31)	-0.026 (-0.18)	0.25* (4.12)	-0.044 (-0.71)	0.1*** (1.35)
LnL	0.89* (4.89)	1.19* (4.29)	1.08** (2.23)	0.79* (3.5)	0.88* (3.46)	1.33* (8.02)	0.53* (3.68)	0.99* (8.26)
Time Trend (T)	-	-	-	-	-	-	-0.72* (-6.07)	-0.14* (-3.08)
LnK2	-0.0044 (-0.44)	0.018** (1.71)	0.0019 0.22	0.07* (5.51)	0.05* (4.47)	0.81* (6.23)	0.024* (4.92)	0.31* (5.93)
LnL2	-0.019 (-0.55)	-0.035 (-0.70)	-0.015 (-0.29)	0.17 (4.94)	0.050*** (1.45)	0.024 (0.77)	0.032** (1.92)	0.037** (1.72)
T2	-	-	-	-	-	-	0.024* (3.09)	0.018* (3.59)
LnK*LnL	0.000133 (0.004)	-0.00086 (-0.021)	-0.022 (-0.46)	-0.21* (-6.47)	-0.10* (-3.65)	-0.047* (-2.9)	-0.054* (-3.68)	-0.084* (4.52)
T*LnK	-	-	-	-	-	-	0.027* (3.58)	-0.013** (2.2)
T*LnL	-	-	-	-	-	-	0.027** (1.90)	0.50* (4.3)
Herfindahl (3 digit)	2.93* (3.81)	0.71*** (1.36)	-0.13 (-0.23)	-0.066 (-0.13)	-0.14 (-0.60)	1.52* (5.6)	-0.19 (-1.23)	0.77* (4.47)
Inefficiency function								
Constant	2.65* (9.11)	2.75* (4.84)	1.05*** (1.56)	2.59* (5.43)	5.09* (4.79)	0.70* (4.03)	5.1* (10.8)	1.7* (9.5)
Predicted Foreigners	0.19 (1.26)	-0.63** (-1.66)	-0.066 (-0.79)	0.29 (1.01)	-4.23* (-2.99)	0.59 (0.53)	-0.4* (-3.54)	-0.19** (-1.97)
Predicted Manager	-0.053 (-0.34)	-0.20 (-0.80)	-0.023 (-0.31)	0.0023 (0.0095)	-2.85* (-2.9)	-0.20*** (-1.34)	-0.15*** (-1.51)	-0.25* (-2.56)
Predicted Employment	0.096 (0.58)	-0.15 (-0.47)	0.036 (0.40)	0.041 (0.13)	-3.69* (-2.78)	0.09 (0.35)	-0.071 (-0.52)	-0.081 (-0.68)
Predicted Domestic	0.064 (0.57)	-0.057 (-0.25)	0.024 (0.81)	0.35*** (1.29)	-2.61* (-2.9)	0.009 (0.068)	-0.0033 (-0.035)	0.021 (0.22)
Firm Size	-0.16* (-3.02)	0.04 (0.38)	-0.019 (-0.098)	-0.096 (-1.04)	-0.94* (-3.69)	0.34* (2.68)	-0.40* (-7.15)	0.037 (0.93)
DummySBC	0.53* (4.94)	1.17* (3.63)	0.14 (0.20)	0.80* (5.03)	1.48* (3.16)	0.46* (4.5)	0.55* (7.53)	0.51* (6.16)
Herfindahl (3digit)	2.45* (2.71)	0.68 (0.75)	0.0051 (0.57)	-0.41 (-0.49)	2.09*** (1.56)	1.01** (2.28)	-0.14 (-0.46)	0.61** (2.19)
Invest/Sales	-0.057 (-1.23)	-0.65 (-0.74)	0.0034 (0.38)	0.28 (0.29)	4.17* (2.63)	0.74** (1.98)	-0.071 (-1.05)	-0.021 (-0.10)
Export/Sales	-0.077 (-0.58)	-0.22 (-0.95)	-0.018 (-0.20)	0.012 (0.064)	0.47 (0.85)	-0.045 (-0.42)	-0.13 (-1.3)	-0.18 (-1.22)
Avg. Labor Cost	-0.57* (17.4)	-0.10* (-8.31)	-0.021* (-3.93)	-0.058* (-6.72)	-0.068* (-3.5)	-0.04* (-17.8)	-0.031* (17.6)	-0.38* (-2.87)
Dummy High Tech	-0.79 (-0.13)	-0.085 (-0.13)	-0.062 (-0.67)	0.31 (0.53)	-0.24 (-0.32)	0.23 (0.40)	0.0022 (0.0038)	0.17 (0.29)
Time of Privatization	-0.034** (-1.98)	-0.028 (-0.80)	0.014 (0.33)	-0.0064 (-0.19)	0.35* (3.02)	0.016** (1.64)	0.0076 (0.68)	-0.19* (-1.73)
Time Trend							-0.31* (6.1)	0.14* (6.13)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean Efficiency	0.37	0.38	0.55	0.51	0.62	0.32	0.35	0.34

Note: *, ** and *** significant at 1%, 5% and 10% respectively.

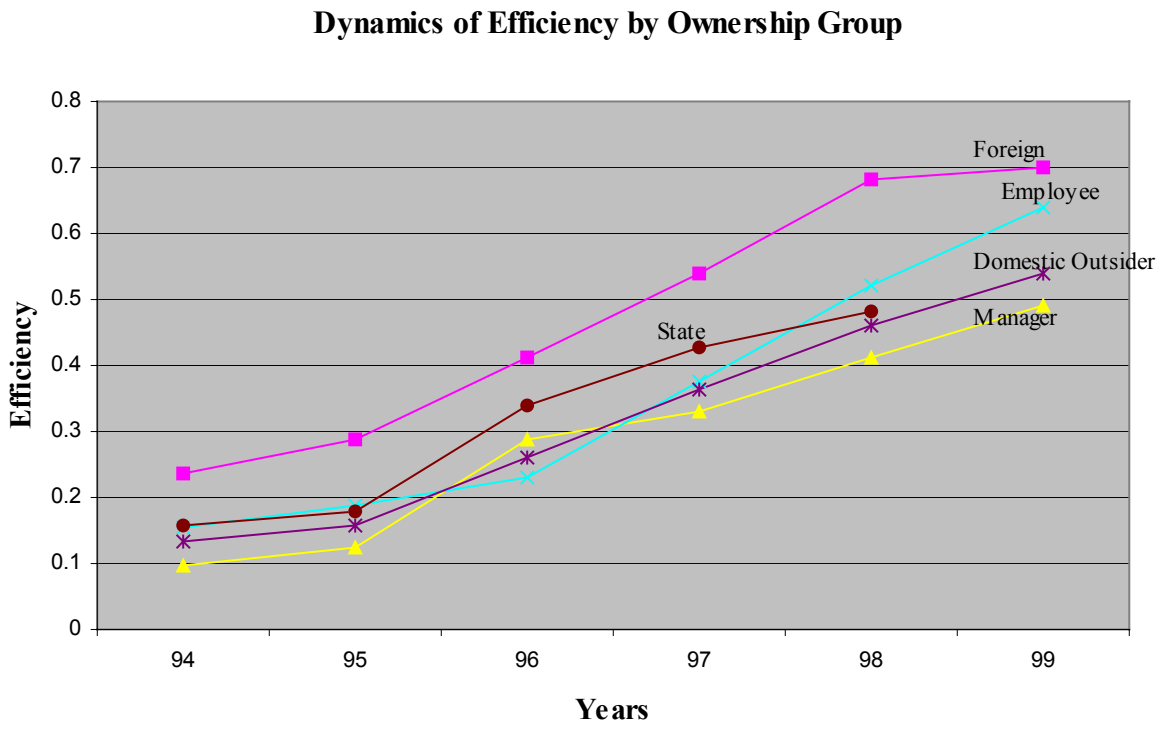
Table 6: Elasticities of Capital and Labor over time.

	1994	1995	1996	1997	1998	1999	Panel	Bal. Panel
Elasticity of Capital	0.051	2.46	0.25	0.61	0.31	12.94	0.166	4.45
Elasticity of Labor	0.732	0.913	0.785	0.69	0.545	3.07	0.5	2.42

Graph 1



Graph 2


Dynamics of Efficiency by Ownership Group
Efficiency
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
94
95
96
97
98
99
Years
Foreign
Employee
Domestic Outsider
State
Manager

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