Determinants of Firm Level Technical Efficiency: A Stochastic Frontier Approach*

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Abstract

By using an empirical approach seldom used in this area for transition economies (namely, stochastic frontiers) we investigate the determinants and dynamics of firm efficiency. This approach allows us to simultaneously estimate the parameters of both the efficiency and the production function. We also use most unusual data --a representative sample of Estonian firms for the period 1993-1999 – and are able to address problems that plague much previous work, such as the endogeneity of ownership. Consequently our findings are more reliable and efficient than most previous estimates. Our main findings are that: (i) compared to employee and state ownership, foreign ownership increases technical efficiency; (ii) firm size and higher labor quality enhance efficiency, while soft budget constraints adversely affect efficiency; (iv) Estonian firms operate under constants returns to scale; (v) the percentage of firms operating at high levels of efficiency increases over time. As such our findings provide support for hypotheses that a firm's ownership structure and its characteristics are important for its technical efficiency.

Keywords: Stochastic Frontier, Technical Efficiency, Transition, Soft Budget Constraints and Ownership Structure.

JEL Classification: C33, D21, D24, G32, J54, L25.

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1. Introduction

The privatization process in transition economies has resulted in the emergence of a variety of ownership structures and has also generated an extensive theoretical debate over which form of private ownership would lead to better restructuring outcomes and higher efficiency levels. This theoretical literature concludes that certain ownership forms are preferred, in particular that outsider ownership is expected to be more efficient than insider ownership (Aghion and Blanchard, 1998). There is also an extensive empirical literature for transition economies, which assesses the effects of different ownership structures on enterprise performance and efficiency. In a comprehensive literature review of that literature, an influential survey by Djankov and Murrell (2002) concludes that, in general, privatization will improve firm performance so that privatized firms will perform better than state owned firms and that concentrated ownership is beneficial for firm performance. They also find that Central and Eastern European countries experienced a larger positive impact of privatization than did CIS countries.

At the same time, as Djankov and Murrell (2002) themselves note, the empirical literature on firm performance and privatization has faced formidable estimation challenges and thus most conclusions are necessarily tentative. Of central importance are issues related to the endogeneity of ownership structures, for example the view that often insiders selected the best performing firms[i]. Several studies find that empirical findings are quite sensitive to attempting to deal with endogeneity problems. In the main studies that grapple seriously with endogeneity find that outsider ownership improves firm performance more than insider ownership (e.g. Earle and Estrin, 1997). Also studies find that particular types of outsider ownership work best. Thus Smith, Cin and Vodopivec (1997) find that foreign ownership improves firm performance most in Slovevia while Frydman et al., (1999) conclude that firms that are owned by domestic outsiders perform slightly better than foreign owned firms. But not all studies that attempt to deal with endogeneity find that all forms of outsider ownership have a large performance edge over all forms of insider ownership (e.g. Jones and Mygind, 2003, for Estonian frims).

In addition other authors have also drawn attention to other difficulties confronting empirical work in this area and, as a result, do not always reach conclusions comparable to those of Djankov and Murrell. For instance, Bevan, Estrin and Schaffer (1999) and Filer and Hanousek (2001) point out that problems related to differences in accounting standards often undermine the credibility of performance variables. Another problem is that many studies may have used the most reliable empirical strategies and that much empirical work may have neglected key issues such as the dynamics of efficiency. Finally, confidence in the reliability of general findings in this field is undermined by the fact that often data samples have been small and not representative.

This paper attempts to respond to these empirical challenges and is distinguished form much previous work in several respects. First, our data are a long and rich panel for a sample of firms that is representative of the Estonian economy and including firms with diverse ownership structures. Second, these data and the technical approach we employ enables us to estimate the impact on the level of firm technical efficiency of several crucial variables, including ownership structures, soft budget constraints and competition. Third, the long time horizon in our data enables us to account for the issue of endogeneity, in a more thorough way than in many other earlier studies. Fourth, our modeling strategy permits us to distinguish between shifts in the production function and changes in technical inefficiency over time. Finally, and most unusually, we examine aspects of the dynamics of efficiency, including presenting evidence of the distribution of efficiency scores over time and across firms with various ownership structures.

The structure of the paper is as follows. In section 2, we discuss the determinants of firm efficiency. In the following two sections the privatization process in Estonia is first outlined and then we discuss our data. This is followed in section 5 by a discussion of the estimation strategy. In the following three sections we present our findings with returns to scale and the dynamics of firm efficiency being discussed in sections 7 and 8. Finally, in section 9, we conclude.

2. The determinants of firm efficiency

In addition to ownership structures, the growing body of theoretical and empirical literature on firm performance and privatization has identified a host of other variables, namely, investment in fixed capital, soft budget constraints, firm trade orientation, the quality of labor, and competition, among others, as determinants of firm performance and consequently firm efficiency (Djankov and Murrell, 2002; Aw, Chung and Roberts, 2000; Brown and Earl, 2001; Frydman et al., 1999). The aim of this section is to briefly discuss how each of these factors affects firm efficiency and establish the direction of the relationship. We begin with a discussion of issues surrounding ownership.

As noted already the bulk of the theoretical literature concludes that certain ownership forms are to be preferred, in particular that outsider ownership is expected to be more efficient than insider ownership. Accordingly, Aghion and Blanchard (1998), stress that privatization to insiders would lead to less restructuring as insiders suffer from lack of capital and expertise. As a result, privatization to outsiders would be desirable for restructuring outcomes. To test these hypotheses, however, has not always been an easy proposition. For one thing, diverse insider and outsider ownership structures have seldom co-existed within one country. In addition, often ownership has been dispersed within firms so that it has not always been able to clearly identify the main owner. In turn this has led to classifications based on dominant as opposed to majority owners. Fortunately, as we shall see, in our case most f these issues do not present large problems and we are able to construct measures for five types of ownership in Estonia, including our being able to separate the two main types of insider ownership (employee and manager), which are often lumped together in other studies.

One common feature of firms in transition economies is that they started the transition process with old technology, which could not be used to produce goods of sufficient quality to compete in both domestic and world markets. As such, a common challenge for these firms is to carry out high investment rates to substitute the old obsolete capital for new advanced technology in order to be able to survive and compete in the market-oriented economy. In return, this will contribute to increases in productivity and thereby efficiency. Under the conditions of under-developed capital markets and weak banking and non-banking sector there will be fierce competition for funds and not all firms would be able to raise all the much needed capital. Consequently, it is expected that firms with better access to finance and higher investment rates will display higher levels of efficiency. However, state-owned firms in transition economies were characterized by lack of financing, possible bankruptcy and soft budget constraints. The existence of soft budget constraints is detrimental for firm efficiency, because it distorts managerial incentives and erodes the effect of competitive pressure. The original definition of soft budget constraints, introduced by Kornai (1980), regarded the action of a paternalistic state, which was not willing to accept social consequences of closing down loss-making firms and, consequently, intervened by bailing them out unconditionally. Nowadays, the notion of soft budget constraints include not only cheap credit provided in the form of direct government subsidies, but also tax arrears, trade credits and cheap loans from the financial sector. In fact, direct budgetary subsidies constitute an insignificant part of financing to firms (Schaffer, 1998). Under these circumstances the other components of soft budget constraints might constitute an important source through which the state and/or other institutions extend support to distressed firms. For instance, the state might postpone the collection of corporate and social security taxes. Another potential source of cheap capital is overdue trade credit to suppliers. However, in this respect, Schaffer (1998) argues that, at least in more advanced transition economies, firms have learnt to apply hard budget constraints to each other.

A final source of soft budget constraints is easy access on the part of distressed or loss-making firms to bank lending through special relations with banks and/or other financial institutions. In order to properly establish the pervasiveness of this channel of soft budget constraints one needs to combine data from both firms and banks. It is tempting to interpret positive net financing to a loss-making firm as evidence of soft budget constraints. This would be the case only if the stated loan has a low economic value to the bank itself.

Overall, the existence of soft budget constraints is likely to lead to lower levels of efficiency. Ascertaining its effect, however, is a difficult task because of the lack of appropriate data to measure it, as is the case with tax arrears, or the noise contained in the available data, as in the case with trade credit and bank loans. However, in view of its importance, in this paper we follow the literature and attempt to ascertain the effect of soft budget constraints by constructing a measure comparable to that used by Schaffer, (1998.)

With respect to trade orientation, it is expected that those firms that produce mainly for export are under the pressure of international competition and, consequently, will utilize resources more efficiently. For instance, exporters can acquire knowledge and expertise on new production methods, product design, etc., from international contacts. In turn, learning-by exporting results in higher productivity of exporters versus non-exporters. However, the positive correlation between productivity and exporting, could simply suggest that only the most productive firms can survive in a highly competitive international environment. The studies of Bernard and Jensen (1999), Clerides, Lach and Tybout (1998) and Aw, Chung and Roberts (2000) find that firms that become exporters are more efficient prior to entry than the non-exporting firms. This suggests that there may be a self-selection problem of more efficient firms self-selecting in the export market. In light of such information, current values of variables of firm characteristics would be endogenous to the current export decision.

It is expected that the higher the level of labor quality, the more efficient the usage of existing technology and the absorption of new technology, which will consequently result in higher efficiency levels. To proxy labor quality we use average labor cost (and assume that a more qualified labor force commands higher wages and salaries.) However, we recognize that the use of average labor cost is potentially problematical since it can also capture the rent extraction effect, i.e., labor cost is high because workers are able to extract rents through higher salaries.

The existence of competitive markets is considered a prerequisite for productive efficiency and a fundamental requirement for efficient allocation of resources in an economy. Competitive product and factor markets induce firms to use more efficiently their inputs or to push inefficient firms out of the market. Accordingly, firms facing domestic competition may restructure since they do not lag far behind other domestic firms, except for local firms with foreign direct investment. For instance, Brown and Earle (1999) find that domestic competition has a significant disciplinary effect on Russian enterprises. Likewise, Carlin et. al. (2001) using a survey of 3300 firms in 25 transition countries find a strong significant impact of the perceived local competition on firm performance. Furthermore, the combined effect of competition and ownership on enterprise performance and efficiency may be mutually reinforcing. During the early writings on the subject, Lipton and Sachs (1990), Blanchard and Layard (1992), Frydman and Rapaczynski (1991) and Boycko, Schleifer and Vishny (1996) viewed both rapid privatization and competition as complements in their effect on enterprise efficiency. That is, it is expected that more competitive markets will enhance the impact of privatization on enterprise efficiency[ii].

Finally, we also consider the effect of other firm characteristics such as firm size and firm's sector affiliation. It is expected that firm size is positively correlated with firm efficiency. If firm size reflects economies of scale, larger firms are able to spread the fixed costs of production over more production units. In other words, size may be associated with lower average costs of production. Also, to account for differences in efficiency levels in different industries and over time, industry and time dummies were included.

3. The Privatization Process in Estonia

Privatization was one of the policies that successive Estonian governments committed themselves to since the beginning of transition. Economic considerations and the power of different groups in policy formulation and implementation led to emergence of a wide range of post-privatization ownership structures. The beginning of privatization dates back to 1986, when, under the perestroika reforms, the quasi-private forms of “small state enterprises” and “new cooperatives” emerged. Early forms of privatization were based on the principle of leasing, according to which the company was leased either collectively, with ownership shares determined by wages received, or individually, with ownership shares determined by individual contributions. Until 1993, around 300 enterprises went through this scheme, whose assets, as reported by Mygind (2000), were later on fully privatized mainly by insiders.

Further support for insiders was established through the law on privatizing small enterprises, which was enacted in December 1990. This law explicitly stipulated that enterprises valued up to 500.000 Roubles would be privatized for cash through auctions, but employees would be the first who would be offered the enterprise. This option was abolished in an amendment of the law in 1992, which also increased the valuation threshold to 600.000 Roubles. However, the adoption of the initial law led to almost 80% of the first round of 450 enterprises to end up in the hands of insiders. The privatization of small enterprises started slowly, but accelerated substantially after June 1992, when Estonia adopted its own currency, kroon, instead of the Russian rouble. The EBRD Transition Report (1999), stressed that, while by the end of 1991 only 16% of small enterprises were privatized, by the end of 1992 this number increased to 50% and in late 1997 it increased to 99.6%.

Differently from the privatization of small enterprises, the privatization of medium and large enterprises reflected the governments’ preferences for core investors and, especially, foreign investors. Although it started slowly, the process gained speed and as documented by

1998, 483 large enterprises earmarked for privatization were already sold to strategic investors through open international tenders for a total value of around 400 million USD, investment guarantees of similar amount and job guarantees of more than 55000 places (Mygind, 2000).

Overall, the privatization process in Estonia is characterized by some initial preference for insider ownership at the beginning of transition, by extensive use of auctions in privatization of small enterprises and international tenders in privatization of medium and large enterprises. Moreover, in later stages of privatization, governments displayed strong preferences for core and foreign investors. The outcome of this process is a highly diverse ownership configuration.

4. Data

Our data consist of annual firm-level observations for Estonian firms for 1993 through 1999. The data are derived from a large and representative sample of 666 firms that cover all the economic sectors and are assembled from diverse sources including company records and a series of ownership surveys that were undertaken by the authors. Prior to using the data, a series of consistency checks is performed and inconsistent data is left out[iii]. Furthermore, we estimate the frontier for three main economic sectors, namely, agriculture, manufacturing, and construction. Accordingly, our final sample consists of 2174 observations over the period 1993-199. Table 2 shows the distribution of the firms over time and the three economic sectors.

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Table 1 & 2 approximately here

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A detailed description of the variables and their definition is provided in Table 1. In order to avoid biases that might arise due to inflation all data is deflated to 1993 prices, using two digit PPI deflators. Most of the variables are self-explanatory, however, the definition of one variable, namely the SBC, requires further discussion. As in Schaffer (1998), it is assumed that a firm has a SBC if it is loss making and is receiving net financing either as subsidies or in the form of lending and increases in debt over interest costs. Then, the SBC for each firm in the sample is constructed as follows:

$$Net\ Financing(t) = \frac{Debt(t) - Debt(t-1) - Interest\ Cost(t)}{Fixed\ Assets(t)} \qquad (6)$$

$$Dummy\ SBC = \begin{cases} 1 \quad if \quad Net\ Financing(t) \succ 0 \quad \& \quad EBITD \prec 0 \\ 0 \quad otherwise \end{cases} \qquad (7)$$

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

In the previous section we stressed that soft budget constraints include cheap credit provided in the form of direct government subsidies, tax arrears, trade credits and cheap loans from the financial sector. Yet, the measure constructed in (6) and (7) is based solely on information on funds received from the financial sector. This is conditioned from the lack of appropriate data to measure other sources of soft budget constraints. Nevertheless, we do not expect all the other channels of soft budget constraints to play a significant role in Estonia. For example, the policies of Estonian governments to run balanced budgets and promote competition have resulted in minimal levels of direct government subsidies, which, according to EBRD Transition Report (2000), have been under 1% of GDP for the period 1996 through 2000. Another source of SBC is the availability of overdue trade credit to suppliers and tax arrears. Limited evidence, however, shows that Estonian firms enjoy some relief in terms of delayed tax collection. For example, the EBRD Transition Report (2000) stresses that the efficiency of the collection of social security tax at the enterprise level in Estonia was 85.6% in 1998 and 76.2% in 1999[iv].

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Table 3 approximately here

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An important contributions of our paper is that the available data enable us to construct a broader range of ownership categories than is typically used in other studies, which usually distinguish only between state, domestic private and foreign owned firms. In addition, even when they can identify insider owned firms, they are not able to separate employee owned firms from managerial owned firms. By contrast, in this paper we are able to distinguish between five ownership groups, namely foreign, domestic, employee, manager, and state owned.

Table 3, shows the dynamics of enterprise ownership structures over time when we classify firms into these five groups on the basis of dominant ownership. A firm is dominantly owned by the group that owns the largest share. The distribution and evolution of ownership structures over time reveal that the number of managerial, domestic and foreign owned firms increases over time. In contrast, starting from 1995, the number of employee and state owned firms decreases over time. This shows considerable movement away from the initial preference for employee ownership.

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Table 4 approximately here

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Table 4 shows the dynamics of means and standard deviations of main variables. Some interesting facts that emerge from this table are that capital stock and value added increase over time while average number of employees (labor) decreases over time. Accordingly, the ratio of capital to labor and value added to labor increase over time. In addition, Herfindahl index is higher during the first years of transition and lower in the last two years. Hence, in the last two years competition increased. Both increased capital intensity and labor productivity as well as increased competition between firms in the industry suggest improvements in firm efficiency. This conjecture is further supported from the fact that the share of exports in total sales and average labor costs increase over time. However, investment levels in new machinery and equipment fluctuate over time, sometimes being quite small.

In order to construct instrumental variables to account for possible endogeneity of both ownership structure as well as other firm characteristics, we use lagged variables and also construct a dummy variable for the soft budget constraint. Consequently, we are able to estimate the frontier only for the years 1995-1999. Since the panel is unbalanced, in order to check on the robustness of the results, we estimate frontiers for both balanced and unbalanced panels. In addition, our data enable us to estimate frontiers separately for the three sectors in our data set, i.e. agriculture, manufacturing and construction. Finally, the length of the panel allows us to investigate the dynamics of efficiency across the different ownership groups. The actual number of firm level observations used in the regression differs from the sample size due to the use of lagged variables.

5. The Estimation Strategy

Since its first introduction by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), the stochastic frontier (SFA) has been increasingly applied in the economics of transition literature[v]. For instance, Konings and Repkin (1998) apply the stochastic frontier approach for Bulgaria and Rumania, Kong, Marks and Wan (1999) and Tong (1999) for China, Jones, Klinedinst and Rock (1999) for Bulgaria, Piesse and Thirtle (2000) for Hungary, Funke and Rahn (2002) for East Germany.

Technical efficiency is a very useful concept to utilize, especially, in a transition economy context, where firms may be maximizing profits or output subject to profit constraints, as well as other goals such as employment. Technical efficiency is a necessary, however, not a sufficient condition for profit maximization, and a necessary condition for most of the constrained output maximization. Therefore, it can be applied within a country to the analysis of firms that have differing objectives (Brada, King and Ma, 1997)[vi].

Technical efficiency scores obtained from the estimation of the stochastic frontier have little use for policy implications and management purposes if the empirical studies do not investigate the sources of inefficiency. Sources of productive inefficiency are, for instance, the degree of competitive pressure, ownership form, various managerial characteristics, network characteristics and production quality indicators of inputs or outputs. Early approaches estimated the variation in inefficiency through a two-step procedure, which consists in first estimating the inefficiency component of the error term and then regressing it against the exogenous variables in the second stage. The problem with this procedure is that, in the first stage inefficiencies are assumed to be identically distributed, however, in the second stage this assumption is contradicted as inefficiencies are given a functional form. Furthermore, in the first stage the expected value of the inefficiency is a constant, but in the second stage it is assumed to vary with the exogenous variables (Coelli, Battese and Rao, 1998). Recent approaches to the inclusion of exogenous variables have brought important changes to the early ones. For instance, today's frontier programs can estimate the variation in inefficiency with a simultaneous estimation using maximum likelihood.

The stochastic frontier applied in the analysis is defined as in Coelli, Battese and Rao (1998):

$$\ln y_{it} = \ln f(x_{it}; t, \beta) + v_{it} - u_{it} \qquad \text{where } i \text{ – denotes the firm} \qquad (2)$$

x_{it} – is a vector of the logarithm of input quantities

t – is a time trend

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

u_{it} – is a non-negative random variable, associated with the technical inefficiency of production, assumed to be identically and half normally distributed, N(μ_{it}, σ_u^2). Mean inefficiencies μ_{it} for each firm are explained by the Z_{ik} variables, which are expected to affect/determine firm level technical efficiency.

$$\mu_{it} = a_0 + a_1 Z_{i1} + a_2 Z_{i2} + a_3 Z_{i3} + \ldots\ldots\ldots + a_k Z_{ik} + a_{k+1} t \qquad (3)$$

where a_k are parameters to be estimated. The time trend parameter is included both in the production function as well as the inefficiency function. The time trend variable in the production function represents the rate of technical change or shifts in the production function over time. This specification makes it possible to consider time varying coefficients and a non-neutral technical change. On the other hand, the time trend variable in the inefficiency function represents changes in technical inefficiency over time.

To estimate (2) and (3) simultaneously the parameterization of Battese and Corra (1977) is applied by replacing σ_u^2 and σ_v^2 with:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad \text{and} \quad \gamma = \frac{\sigma_u^2}{\sigma^2} \qquad (4)$$

Maximum likelihood estimates of β, σ^2 and γ are obtained by estimating the maximum of the log-likelihood function as defined in terms of this parameterization. The maximum likelihood estimation is performed with the frontier program “Frontier 4.1” (Coelli, 1996). Prior to panel estimation, the data was mean-differenced to obtain the fixed effects estimates[vii]. Technical efficiencies are then retrieved calculating the expectation of technical efficiency, $TE_{it} = exp(-u_{it})$, for a given distributional assumption for technical inefficiency effects[viii].

It would be highly desirable to carry out the analysis with the optimal model and the appropriate functional form of the production function. Unfortunately, none of them is know *a priori*. Instead, they will have to be determined from the data at hand. Consequently, before actually reporting and interpreting the empirical results, we first report the results of a number of tests performed that allow us to select the appropriate functional form of the production function as well as the appropriate model to be estimated.

The results of the aforementioned tests are reported in Tables 5A and 5B. Likelihood ratio tests were performed to test the various null hypotheses[ix]. These tests are performed for the three economic sectors and for both, cross sections and panel data.

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Tables 5A & 5B approximately here

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The first test that we perform is on the specification of the production function that best represents the data. The stochastic frontier accommodates both Cobb-Douglas and Translog production functions. Instead of assuming an *ad hoc* functional form, we test for the appropriate specification that bests fits the data. The frontier models that we test are the following:

Cobb-Douglas: $$y_{it} = \beta_0 + \sum_{j=1}^{2} \beta_j x_{jit} + \beta_t t + v_{it} - u_{it} \quad (8)$$

Translog: $$y_{it} = \beta_0 + \sum_{j=1}^{2} \beta_j x_{jit} + \beta_t t + \sum_{j=1}^{2}\sum_{h=1}^{2} \beta_{jh} x_{jit} x_{hit} + \beta_{tt} t^2 + \sum_{j=1}^{2} \beta_{jt} x_{jit} t + v_{it} - u_{it} \quad (9)$$

where j, h – inputs (capital, labour)

The null hypothesis is that Cobb-Douglas is the appropriate functional form. As seen from the tables, the likelihood ratio (LR) tests lead to rejection of the null hypothesis, accepting the Translog as the appropriate functional form in all cases (for the three economic sectors), except for the manufacturing sector in 1995. Given that the Translog function is the generally accepted functional form, in what follows we report the estimation results solely for the Translog function.

The second test we perform is to determine whether the inefficiency effects need to be included in the model. Alternatively, if inefficiency effects do not matter we do not need to estimate a stochastic frontier model but rather an augmented average production function, because the firm is already operating on the technically efficient frontier. The null hypothesis then is: $\gamma = \alpha_0 = \alpha_k = 0$, i.e., the systematic and random technical inefficiency effects are zero, hence, neither the constant nor the inefficiency effects are at all necessary in the model. The null hypothesis that the vector γ is equal to zero, is decisively rejected over time and across the three economic sectors, suggesting that inefficiencies are present in the model and that running average production functions is not an appropriate representation of the data. The closer γ is to unity, the more likely it is that the frontier model is chosen. From Tables 5A and 5B we see that the value of γ is in between 0.7-0.95 in most cases. This, furthermore, implies that for a transition country like Estonia inefficiencies have been persistent during the whole period under consideration.

The third hypothesis we test is whether the technical inefficiencies in the model are or are not a function of the explanatory variables we consider. Hence, the null hypothesis is $\alpha_k = 0$, i.e., all inefficiency variables, except for the constant, are jointly equal to zero. Again, the null hypothesis is rejected, confirming that the joint effect of these variables significantly affects inefficiency.

The fourth test we perform is whether the production process of Estonian firms has been affected by technical change. The null hypothesis is that $\beta_t = \beta_{tt} = \beta_{jt} = 0$, i.e., the coefficients in front of the time trend variable, squared time trend variable, and its interaction with inputs are jointly equal to zero. The null hypothesis is rejected, suggesting that Estonian firms have experienced technical change during this time period. The marginal effect of the technological change on firm productivity is estimated by taking the derivative of equation (9) with respect to time, evaluated at the geometric mean of the respective variables. We find that in all the three sectors there has been technological progress. This means that Estonian firms produce more output for each level of input. This may be the result of efficiency improvements, technology upgrading or scale economies, or a combination of the three. However, since we find evidence of constant returns to scale (in section 7) a combination of the earlier two could explain this finding.

Turning to the estimation issues, the estimation of firm efficiency or firm performance usually faces many difficulties, mainly stemming from the endogeneity of different firm characteristics, such as its ownership structure, trade orientation, investment in fixed capital, and soft budget constraints.

It is of paramount importance to distinguish between two types of endogeneity with respect to the ownership structures. The first type of endogeneity[x] stems 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 and informed groups at the time had an advantage in privatizing them. For instance, potential employee owned firms may have paid close attention to the characteristics of the firm before acquiring or retaining its ownership. Hence, performance measures also determine ownership structures. The best way to correct for this type of endogeneity is to be able to account for the pre-privatization performance of firms. For instance, Frydman et al. (1999), include in the estimation a dummy variable that captures pre-privatization differences between state-owned and privatized firms (the so called treatment effect) and estimate a fixed effects model. They confirm that the performance of firms ready for privatization, but not privatized yet, is close to that of state owned firms rather then privatized ones, underlining, that the effects of privatization are real. Anderson, Korsun and Murrell (2000) approach this problem by using instrumental variables. Suitable instruments are available given the idiosyncratic feature of the privatization program. Instruments used are the date at which the enterprises' privatization plan was approved, the number of private shares in the enterprise at the time of privatization, and employment at the time of privatization. Correcting for the endogeneity arising from pre-privatization performance variables has been the main challenge in the privatization literature, especially since it requires either having the firms present in the sample for the period before and after privatization, or possessing detailed information on the privatization process of firms.

The second type of endogeneity is correlated with the potential correlation of right-hand side variables such as dummies on firm ownership structure, trade orientation and SBC with the error term. When firm ownership structure is used as a right-hand side variable this problem arises because in equilibrium, different owners will determine their optimal ownership share based on various firm characteristics, among which is firm productivity or performance. If left unaccounted for, this results in inconsistent estimates. A potential solution to the problem is the use of instrumental variables approach, i.e., the endogenous variables in the model, the ownership ones in our case, are instrumented with a set of variables that are perfectly correlated with them but not with the error term. The literature on determinants of ownership structures is large and it has suggested that variables such as firm profitability, labor productivity, capital intensity, current and future financing requirements, firm size as well as industry specific variables, all appropriately lagged, would serve as instruments for ownership dummies. Yet, this procedure imposes heavy requirements on data. In the paper, we control for this type of endogeneity in the same fashion as Earle, Estrin and Leschenko

(1996), i.e., by instrumenting current ownership structure of firms with its previous lag[xi]. The advantage of using lags of ownership structure as instruments in the estimation of the frontier is that we are still able to estimate equations (2) and (3) simultaneously.

Turning to firms' trade orientation, papers by Roberts and Tybout (1997), Clerides, Lach and Tybout (1998), Bernard and Jensen (1999), Aw, Chung and Roberts (2000), etc., show that exporting firms are larger, more productive, pay higher wages and survive longer than firms that do not export. The literature has proposed two main reasons that can explain the positive correlation between firm productivity and exporting. First, exporters can acquire knowledge and expertise on new production methods, product design, etc., from international contacts. In turn, learning-by exporting results in higher productivity of exporters versus non-exporters. Second, the positive correlation between productivity and exporting, could simply suggest that only the most productive firms can survive in a highly competitive international environment. Hence, the most efficient firms self-select into the export market. In light of such information, current values of firm level export intensity variable would be endogenous. Similarly, firms' decisions to invest in new machinery and equipment depend on past and current levels of output and profit, which in turn are also affected by investment rates.

With respect to soft budget constraints, we do know that soft budget constraints hamper restructuring of firms because of the lack of productivity improvements and the operation of unprofitable production activities (Djankov and Murrell, 2002). Hence, firms with soft budget constraints are expected to be less efficient than the other firms. On the other hand, by construction/definition, firms in financial distress and, hence, not performing well fall in the group of firms with soft budget constraints. Hence, the causality between firm efficiency and soft budget constraints is not clear.

Overall, we account for these possible sources of endogeneity, employing lagged values of these firm characteristics as instruments for the respective variables.

6. The Estimation Results

The tests on the appropriate functional form of the production function that best represents the data revealed that, the Translog specification (equation 9) is the preferred one. Therefore, in this section we report the empirical results obtained from estimating the Translog function only. The model is estimated for each cross-section and both fixed effects balanced and unbalanced panels for the manufacturing sector, as well as for the fixed effects unbalanced and balanced panels for the agriculture and construction sectors.

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Tables 6 & 7 approximately here

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The estimates of the inefficiency function are reported in the second part of Table 6 for the manufacturing sector and Tables 7 for agriculture and construction. In interpreting the results of the inefficiency function one should keep in mind that a negative coefficient reflects reduced firm inefficiency and, hence, increased efficiency. The results of Table 6 reveal that ownership structure is generally a significant determinant of firm level inefficiency. For instance, the results show that foreign and managerial ownership increase firm efficiency compared to employee owned firms for years 1996 and 1998. However, panel estimates show that only foreign ownership increases firm efficiency compared to employee ownership. Further, other ownership forms significantly increase firm inefficiency compared to employee ownership. The finding that foreign ownership increases firm efficiency more than the other forms of private ownership is consistent with the findings of Smith, Cin and Vodopivec (1997) and De Mello (1997). Reasons related to access to advanced technology, capital and better organization are expected to have contributed to higher firm efficiency. Slightly surprising is the result that domestic outsider ownership does not produce efficiency gains over employee ownership.

Among other variables, those that significantly affect firm efficiency are firm size, average labor cost (labor quality), the share of exports in net sales, the share of investment in fixed capital to net sales, and soft budget constraints (SBC). The results reveal that the number of significant parameters increases with panel estimates. Among these variables, only the effect of the SBC and average labor cost is robust across all specifications, cross-sections and panel estimations. More specifically, the effect of soft budget constraints is positive and significant, except in 1996. This result suggests that, as expected, the availability of easy financing is detrimental to firm efficiency. Several other studies have illustrated that SBC erodes firms' incentives for restructuring. For instance, Coricelli and Djankov (2001), and Claessens and Peters (1997), using a similar measure of SBC find that loss-making enterprises received significantly more bank credit than did the other firms. While, Djankov and Murrell (2002) argue that hardened budget constraints have a beneficial effect on restructuring. In addition, the effect of average labor cost is negative and significant across all specifications, implying that the availability of qualified workers, at firm level, results in higher firm level efficiency. In contrast, the effect of investment in fixed capital is not consistent across cross sections with it increasing firm inefficiency for 1997 and 1998. One explanation for this finding is that investment in fixed capital takes away productive resources and it may take time to become fully operational.

Turning to the other variables we observe that they are significant only across panels. For example, firm size significantly affects firm efficiency, in that larger firms are more efficient, and this result remains robust across both balanced and unbalanced panel estimates. This conclusion is in line with the argument that large firms exploit economies of scale and produce at lower average cost per unit. Further, the share of investment in sales also significantly increases firm efficiency across both panels, while she share of exports to sale significantly increases efficiency only in the unbalanced panel, suggesting that export oriented firms which face international competition tend to be more efficient.

The results for the agriculture and the construction sectors reported in Table 7 reveal a slightly contrasting picture with respect to the impact of ownership structure and firm characteristics. Focusing on the ownership variables we see that for the agriculture sector foreign and managerial ownership significantly increase firm efficiency while for the construction sector it is the domestic and state ownership that lead to increases in efficiency compared to employee owned firms. With respect to the firm characteristics, for the agriculture sector, investment increase firm efficiency and soft budget constraints are detrimental to firm efficiency. In addition, the age of privatization improves efficiency in that firms that have been privatized earlier are more efficient. For the construction sector, firm size, investment and age of privatization increase firm efficiency, while export orientation and average labor cost decreases firm efficiency.

Overall, the results reported confirm the conjectures on the significant effect of most firm characteristics on firm level efficiency. These results are more in line with those of Brada, King and Ma (1997) who find an interval of 40-80%, and Jones, Klinedinst and Rock (1998) who find an interval of 60-70% for Bulgaria. In contrast, Danilin et al. (1985), in a study of a large sample of Russian cotton refining enterprises, find that more than half of the enterprises in their sample have estimated rates of 94% technical efficiency, and the overall mean was 92.9%. Similarly to Danilin et al. (1985), Piesse and Thirtle (2000) found a 93.4% mean efficiency for the agriculture sector and of 91.8% for the manufacturing sector. This variance in results obtained could be due to the fact, explained by Smith et al. (1997), that the level of efficiency will depend significantly from the functional form and the level of aggregation chosen. More specifically, they stress that the efficiency level will be lower when capital and labor are the only inputs.

7. Input Elasticities and Returns to Scale

One of the economic distortions of transition economies was the excessive use of inputs in the production process. This phenomenon manifested itself in lower productivity and technical efficiency. The elimination of such inefficiencies was one of the goals of firm restructuring. Therefore, it would be interesting to know whether over time Estonian firms were operating under decreasing, constant or increasing returns to scale. Input elasticities for the translog production function are calculated as follows:

$$e_j = \frac{\partial \ln(y_i)}{\partial \ln(x_{ji})} = \beta_j + \sum_{j=1}^{2} \beta_{jh} \ln x_j + \beta_{jt} \qquad (10)$$

The variance of elasticities is:

$$Var = \lambda_j \hat{\Omega}(\hat{\theta}) \lambda_j' \qquad (11)$$

where θ is the vector of maximum likelihood estimators of parameters (β_j), and λ_j is a row vector of the same dimension with zero entries except when corresponding to β_j and β_{jh}, elements of θ. $\hat{\Omega}(\hat{\theta})$ is the estimated covariance matrix for θ. Its components are part of the variance covariance matrix of the maximum likelihood estimation of the frontier program, Frontier 4.1.

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Table 8 approximately here

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Input elasticities and returns to scale, calculated over time and across all sectors, are reported in Table 8. A clear pattern emerging from the results is that labor has a higher elasticity than capital, and that the elasticity of labor is significant in all cases. In addition, although capital has smaller elasticities, they are always significant except for the construction sector in the balanced panel. Given such a pattern we focus on interpreting the results for the panel estimations only. The results show that labor accounts for 72% of the value added (the dependent variable) for both the unbalanced and the balanced panel, in the manufacturing sector. It accounts for almost 66% for the agriculture sector and 91% for the construction sector. While this pattern of input elasiticities would not be feasible under a market system, it is not surprising in the context of a transition economy, characterized by outdated and labor-intensive technology.

Returns to scale are calculated as the sum of individual elasticities from equation (10) as follows:

$$\upsilon = \sum_{j=1}^{2} e_j = \sum_{j=1}^{2} \beta_j + \sum_{j=1}^{2}\sum_{h=1}^{2} \beta_{jh} \ln x_j + \sum_{j=1}^{2} \beta_{jt} \qquad (12)$$

In testing the deviation of actual returns to scale from constant returns to scale the test statistic is the following:

$$S = \frac{\upsilon - 1}{\sqrt{\Omega(\upsilon)}} \quad \text{where } \Omega(\upsilon) = \gamma_j \hat{\Omega}(\hat{\theta})\gamma_j' \text{ and } \gamma = \sum_{j=1}^{2} \lambda_j \qquad (13)$$

This test statistic has a t-distribution. If the value of returns to scale is significantly larger than unity then the firm operates in the increasing returns to scale region, while if it is significantly less than unity then the firm operates in the decreasing returns to scale region.

The results of Table 8 show that the sum of elasticities is usually less than unity except for year 1995 and the unbalanced panels for the agriculture and construction sector. The null hypothesis of constant returns to scale is accepted in all cases. Hence, firms in Estonia, on average, operate with the right input mix and are at the right point of their production function. How then does this evidence reconcile with the efficiency improvements reported in Tables 6 and 7? One potential explanation is that efficiency gains have been achieved through the decrease in the size of firms. As observed from Table 4, over time firms have reduced in size as evidenced by the decline in the average employment, and have become more capital intensive as evidenced by the increase in capital and the pattern of capital intensity ratio. This data shows that Estonian firms, at the early transition, were characterized as more labor intensive and over time substituted capital for labor, which may have contributed to higher efficiency levels. However, Tables 6 and 7 reveal that firm size positively affects firm efficiency. These findings are not necessarily contradictory as over time firms increase efficiency by becoming more capital intensive with larger firms still being more efficient.

8. The Dynamics of Firm Technical Efficiency.

In this section we explore the dynamics of firm efficiency using the pattern of efficiency scores calculated from the balanced panel. We opt for the use of the balanced panel to avoid biases generated by the entry and exit of firms over time. The distributional pattern of firm level efficiency, across firms of different ownership structures, as well as its evolution over time, is a neglected issue in the literature. In investigating the distributional patterns of firm efficiency, 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, firm level efficiency is determined from different firm level characteristics, and, as such, we expect some firms to be more efficient than others. Accordingly, we create five 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, respectively. Graph 1, Graph 3 and Graph 5 represent the distribution of firms according to this grouping over time for the manufacturing, agriculture and constructing sector, respectively.

Graph 1, shows the distribution of firms belonging to the five efficiency groups for manufacturing sector. From this graph we see that around 50% of firms in 1995 were operating at the 0-20% and 20-40% 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 oriented economy. However, the percentage of firms belonging to these levels of efficiency has decreased over time, while 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 argue that reasons related to privatization, such as restructuring and the introduction to market competition might have played an important role to increasing firm efficiency. A slightly different pattern of increased firm efficiency over time emerges from Graph 5, for the construction sector. The percentage of firms belonging to the last efficiency group (80-100 %) has somewhat decreased over time, while the percentage of firms belonging to the fourth efficiency group (60-80%) has increased over time with the other groups experiencing marginal changes. In contrast, Graph 3 shows that efficiency distributions for the agriculture sector have been quite stable over time, with the leas efficient group shrinking in size. Overall, the conclusion to be drawn from these graphical illustrations is that over time Estonian firms, on average, across all sectors have become more efficient as expressed by the increasing percentage of them operating in high efficiency levels.

Further, we investigate the dynamics of efficiency across different ownership groups and over time. Graph 2 shows that, firms in the manufacturing sector display increases in efficiency over time. Among them, foreign firms are the most efficient over the whole period and their efficiency persistently dominates that of the rest of ownership structures. Employee owned firms follow up 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. This however, may also reflect the fact that employees have bought out the best firms because of insider's information. Also, this graph also shows that state owed firms operate at the lowest level of technical efficiency until 1997. A relatively similar picture emerges in the construction sector, displayed in Graph 6, where foreign owned firms display the highest level of technical efficiency, followed by the domestic outsiders until mid 1997, while employee owned firms display lower levels of technical efficiency, however, increasing over time.

With respect to the agriculture sector, foreign firms entered the industry only in the last two years (Graph 4). However, they are distinguished for their high level of technical efficiency compared to the other ownership structures. The fact that foreign firms entered late in the sector might suggest a protectionist policy of the government in order to increase its competitiveness. Contrary to the manufacturing sector, the arguments against insider ownership, especially employee ownership, find support here in that insider owned firms not only display lower efficiency levels than outside private owned firms but also do not experience increases in efficiency over time. In addition, the balanced panel for the agriculture sector contains no state owned firms, except for in 1995, as they are privatized over time.

Overall, these results provide support to the theoretical predictions that privatization to foreign ownership leads to higher firm efficiency. Furthermore, they provide partial support to the theoretical arguments on the advantages/disadvantages of insider ownership. More specifically, employee owned firms perform second best to foreign firms and display increasing efficiency over time in the manufacturing sector. In contrast, employee owned firms are ranked the last both in the construction and agriculture sector. In order to fully explain the cross sector differences one needs to account for the pre-privatization performance of firms. That is, it might be possible that given groups of owners had access to superior information and, consequently, privatized better performing firms. We could speculate, however, on these differences based on the sequence of privatization in these particular sectors. The employee owned firms in the manufacturing sector are mostly those that went through the leasing program at the beginning of transition and, consequently, were privatized first. It is highly likely that these firms were better performing than those left for the centralized privatization program. In contrast, employee owned firms in agriculture and construction sectors are likely successors of collective farms. In their privatization priority was given to private investors and usually those that did not attract any investors remained under employee ownership[xii].

9. CONCLUSIONS

Using a representative panel of Estonian firms over the period 1993-1999 we investigate the determinants of firm efficiency as well as its dynamics, applying the stochastic frontier approach. The major benefit of using this method is that the parameters of both firm level efficiency and production function are estimated simultaneously, resulting in efficient estimates. Score efficiencies, obtained from the estimation of frontier, are then used to investigate the dynamics of efficiency, which is a long neglected issue in the literature, as well as firm's returns to scale.

Our findings provide support to the hypothesis that a firm's ownership structure is important for the firm's technical efficiency. For instance, we find that productive efficiency increased over time across all ownership groups, with foreign owned firms being the most efficient over time and across the three main economic sectors agriculture, manufacturing and construction. In addition, employee owned firms have been the second best performing group of firms for the manufacturing sector. This finding is consistent with the argument 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 (Dow, 2003). However, the fact that foreign and employee owned firms have the highest levels of efficiency may also reflect the fact that they have bought out the best performing firms at the beginning of the privatization Earle, Estrin and Leschenko (1996). Nevertheless, the fact that efficiency for both groups increased over time suggests that this argument might hold only for the beginning of privatization and that indeed both forms of ownership have contributed significantly to firm efficiency, at least for the manufacturing sector. In contrast, employee owned firms are ranked the last, both, in the construction and agriculture sector. The efficiency distributions for these sectors support the arguments of Blanchard and Aghion (1996) that privatization to outsider private owners leads to increased firm efficiency as opposed to privatization to insiders. This conclusion, however, might not be as strong if one takes into account the pre-privatization status of these firms. In fact, during privatization, in these sectors priority was given to private investors and usually those firms that did not attract any investors remained under insider ownership. Obviously the restructuring of these firms needed significant investment in new capital and up to date technology.

With respect to other firm characteristics, we find that firms that are foreign and managerially owned, larger in size, with higher labor quality, and are privatized in the early stages of transition, display higher levels of efficiency and as expected, soft budget constraints are detrimental to firm efficiency. These results are consistent with the existing findings in the literature.

Given that foreign ownership produces the highest levels of efficiency, the government should strongly promote foreign direct investments, especially in form of joint ventures. This way the government would promote economic growth. Furthermore, this policy should be accompanied with hardening of soft budget constraints and promotion of training of employees as important determinants of firm level efficiency.

We also find evidence of constant returns to scale across all economic sectors with efficiency increasing over time. Estonian firms seem to increase efficiency by becoming more capital intensive with larger firms still being more efficient.

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APPENDIX

Table 1: Variable Definition

Variables	Definition
Value Added	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.
Dominant Ownership Dummy	This is a dummy equal to 1 if the share in equity owned by a group for that year is greater than that owned by any other group.
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)	Earnings before Interests, Profit Taxes and Depreciation are equal to 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.
Age of Privatization	Shows the number of years a firm has been operating as private.
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[xiii]	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 technical changes in productivity. 2) Also included at the inefficiency function to account for temporal changes in technical inefficiency.
d_j	Industry dummy, constructed on a two-digit level industry classification

Note: All data, except average number of employees and ownership shares, has been deflated to 1993 prices before variable construction.

Table 2: The Distribution of Firms by Year and Economic Sectors

Year	Agriculture	Manufacture	Construction	Total
93	55	218	44	317
94	47	216	48	311
95	45	264	61	370
96	35	256	60	351
97	37	229	53	319
98	34	197	44	275
99	28	170	33	231
Total	281	1,550	343	2174

Table 3: The Dynamics of the Dominant Ownership Structure.

Year	Domestic Outsider	Employees	Foreign	Managers	State	Total
93	64	40	28	27	158	317
94	74	45	33	35	124	311
95	80	40	34	39	177	370
96	98	37	45	49	122	351
97	85	23	45	55	111	319
98	76	21	42	47	89	275
99	93	30	54	53	1	231
Total	570	236	281	305	782	2174

Table 4: Mean and Standard Deviations of Main Variables over Time.

Year	Value Added	Capital	Labor	Capital/ Labor	VaAdded/ Labor	Herfindahl	Avg. Labour Cost	[1]Export/Y	Invest./Y
93	4758.63 (11128)	5513.48 (13669.16)	182.11 (380.09)	33.79 (86.63)	24.78 (33.84)	0.27 (0.16)	3019.46 (5698.6)	.	0.400 (2.79)
94	4306.66 (10151.71)	5747.13 (14757.23)	152.33 (275.62)	50.58 (217.31)	29.12 (45.9)	0.28 (0.18)	3333.58 (6422.13)	0.24 (0.30)	0.26 (1.87)
95	3722.41 (8965.83)	5480.89 (13123.93)	152.30 (260.88)	45.81 (193.4)	23.41 (32.0)	0.24 (0.17)	2770.80 (5214.29)	0.25 (0.31)	0.17 (0.91)
96	5087.05 (10481.34)	6077.55 (15186.6)	152.72 (284.24)	46.74 (195.36)	32.28 (30.28)	0.25 (0.17)	4014.55 (7755.55)	0.26 (0.32)	0.099 (0.28)
97	6216.15 (11537.03)	6534.45 (14987.78)	145.73 (255.19)	51.47 (159.25)	55.16 (298.65)	0.26 (0.19)	4344.16 (7708.72)	0.28 (0.32)	0.094 (0.19)
98	6559.6 (10847.16)	8235.95 (16677.36)	151.53 (255.83)	54.58 (97.17)	43.58 (38.05)	0.22 (0.18)	4895.68 (8033.01)	0.27 (0.32)	0.19 (1.42)
99	6991.69 (11925.39)	9887.60 (21169)	130.96 (174.37)	65.01 (100.59)	38.69 (163.31)	0.24 (0.19)	4779.39 (6832.42)	0.29 (0.33)	0.07 (0.12)
Total	5249.60	6591.39	153.39	48.87	34.69	0.25	3801.45	0.26	0.18

Note: [1] Export data for year 1993 is missing.
[2] This is the total number of observations over time excluding missing values of respective variables.

Table 5A: Hypotheses Tests Results for Manufacturing

Manufacturing							
Test 1: H_0: Cobb-Douglas is the appropriate functional form versus Translog. Test Statistic ($\chi^2_{3,0.95}$) = 7.81 (Panel $\chi^2_{6,0.95}$ =12.59)							
	1995	**1996**	**1997**	**1998**	**1999**	**Unbalanced Panel**	**Balanced Panel**
Test Statistic (Likelihood Ratio)	4.42	9.96	60.16	12.56	16.42	76.14	37.48
Result	Accept	Reject	Reject	Reject	Reject	Reject	Reject
[1]**Test 2:** H_0: $\gamma = \alpha_0 = \alpha_k = 0$ Cross-Section: ($\chi^2_{24,0.95}$) = 35.827 Panel: ($\chi^2_{25,0.95}$) =37.066							
γ **value**	0.89	0.84	0.92	0.84	0.85	0.89	0.82
Test statistic (Likelihood Ratio)	113.32	151.47	172.97	162.66	95.31	557.1	429.07
Result	Reject	Reject	Reject	Reject	Reject	Reject	Reject
Decision	Front	Front	Front	Front	Front	Front	Front
Test 3: H_0: $\alpha_k = 0$ Cross Section $\chi^2_{22,0.95}$ =33.92 Panel: $\chi^2_{23,0.95}$ = 35.17							
Test Statistic (LR)	76.44	101.46	101.92	109.2	71.02	315.74	255.12
Result	Reject	Reject	Reject	Reject	Reject	Reject	Reject
Test 4: H_0: $\beta_t = \beta_{tt} = \beta_{jt} = 0$ $\chi^2_{4,0.95}$ =9.49							
Test Statistic (LR)	-	-	-	-	-	9.82	9.54
Result	-	-	-	-	-	Reject	Reject

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

Table 5B: Hypotheses Tests Results for Agriculture and Construction

Agriculture			Construction	
Test 1: H_0: Cobb-Douglas is the appropriate functional form vs. Translog. $\chi^2_{6,0.95}$ =12.59				
	Unbalanced Panel	**Balanced Panel**	**Unbalanced Panel**	**Balanced Panel**
Test Statistic (Likelihood Ratio)	16.42	36.22	12.94	14.14
Result	Reject	Reject	Reject	Reject
[1]**Test 2:** H_0: H_0: $\gamma = \alpha_0 = \alpha_k = 0$ $\chi^2_{14,0.95}$ =23.069				
γ **value**	0.79	0.56	0.87	0.75
Test stat (Likelihood Ratio)	88.05	85.16	83.37	39.99
Result	Reject	Reject	Reject	Reject
Decision	Frontier	Frontier	Frontier	Frontier
Test 3: H_0: $\alpha_k = 0$ $\chi^2_{12,0.95}$ = 21.03				
Test stat (Likelihood Ratio)	61.24	83.86	40.8	20.86
Decision	Reject	Reject	Reject	Reject
Test 4: H_0: $\beta_t = \beta_{tt} = \beta_{jt} = 0$ $\chi^2_{4,0.95}$ =9.49				
Test stat (Likelihood Ratio)	17.84	30.84	10.48	11.92
Decision	Reject	Reject	Reject	Reject

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

Table 6: Cross-Section Frontier Estimation of the Translog Production Function. Manufacturing Sector.

Production	1995	1996	1997	1998	1999	Fixed Effects UnBalanced	Fixed Effects Balanced
Constant	5.34*** (3.48)	4.48*** (5.48)	3.92*** (6.00)	3.88*** (5.75)	3.41*** (3.96)	0.26*** (23.84)	0.21*** (13.35)
LnK	0.010 (0.06)	-0.173 (-0.99)	0.155 (0.80)	-0.040 (-0.26)	0.111 (0.59)	0.146 (1.02)	0.45*** (2.81)
LnL	0.94** (2.20)	1.07*** (4.00)	0.69** (2.33)	1.09*** (4.20)	1.135*** (3.73)	0.027 (0.10)	0.39* (1.41)
LnK2	-0.026* (-1.82)	0.039*** (2.90)	0.082*** (5.1)	0.031*** (2.98)	0.029*** (2.34)	0.002 (0.25)	0.015** (1.97)
LnL2	-0.044 (-0.80)	0.015 (0.41)	0.219*** (5.69)	-0.011 (-0.26)	0.020 (0.42)	0.149*** (3.77)	0.165*** (4.11)
LnK*LnL	0.076* (1.61)	-0.059* (-1.59)	-0.257*** (-7.31)	-0.046* (-1.61)	-0.078** (-2.18)	-0.063** (-1.84)	-0.142*** (-4.22)
Time Trend (T)	-	-	-	-	-	0.129** (1.71)	0.11* (1.37)
T* LnK	-	-	-	-	-	0.054*** (6.24)	0.039*** (4.63)
T* LnL	-	-	-	-	-	-0.052*** (-3.58)	-0.022* (-1.45)
Time Trend Squared	-	-	-	-	-	-0.035*** (-4.02)	-0.038*** (-4.31)
Inefficiency Function							
Constant	3.49*** (2.68)	2.63*** (2.92)	1.36* (1.35)	1.41* (1.43)	1.83** (2.05)	-5.44*** (-5.14)	-3.79*** (-3.96)
Dummy Foreign$_{t-1}$	0.137 (0.48)	-0.87* (-1.34)	0.33 (0.61)	-0.046** (-2.08)	0.066 (0.12)	-1.63** (-2.24)	-2.72*** (-2.80)
Dummy Manager$_{t-1}$	-0.006 (-0.02)	-0.194* (-1.39)	-0.403 (-0.84)	-0.054 (-0.11)	0.057 (0.10)	2.74*** (3.48)	1.57*** (1.75)
DummyDomestic$_{t-1}$	0.24 (1.11)	-0.199 (-0.48)	0.084 (0.19)	0.560 (1.17)	0.428 (0.80)	2.85*** (4.29)	3.41*** (3.58)
Dummy State$_{t-1}$	0.31 (1.08)	0.407 (0.66)	-0.26 (-0.45)	0.259 (0.46)	0.112 (0.19)	2.67*** (3.51)	2.84*** (3.31)
Firm Size$_{t-1}$	0.039 (0.19)	-0.170 (-1.21)	-0.089 (-0.66)	-0.182 (-1.22)	-0.170 (-1.21)	-0.796* (-1.58)	-2.174*** (-2.72)
Avg. Labor Cost$_{t-1}$	-0.059*** (-8.92)	-0.13*** (-8.33)	-0.079*** (-4.41)	-0.064*** (-3.55)	-0.039*** (-3.52)	-0.015** (-1.83)	-0.093*** (-4.36)
Invest/Sales $_{t-1}$	-0.082*** (-3.33)	0.069 (0.91)	0.881*** (3.33)	1.459** (2.08)	0.091 (0.55)	-0.136** (-2.06)	-0.104* (-1.39)
Export/Sales $_{t-1}$	-0.008 (-0.04)	0.017 (0.04)	0.048 (0.14)	0.014 (0.04)	0.069 (0.25)	-2.902*** (-3.09)	1.69 (1.21)
Dummy SBC $_{t-1}$	0.84*** (4.45)	0.732 (0.80)	0.904*** (3.26)	1.128*** (3.33)	0.425* (1.53)	3.86*** (5.77)	1.789*** (2.88)
Herfindahl (3digit)	-0.137 (-0.19)	1.102 (1.22)	-0.306 (-0.43)	0.412 (0.50)	0.221 (0.30)	-0.980 (-1.00)	-1.58* (-1.47)
Age of Privatization	0.013 (0.22)	0.171* (1.33)	-0.011 (-0.14)	0.017 (0.29)	-0.021 (-0.40)	0.162 (0.88)	-0.044 (-0.21)
Time Trend	-	-	-		-	-0.018 (-0.12)	0.102 (0.55)
Dummy High Tech	-0.211 (-0.33)	-0.698 (-0.98)	1.028* (1.35)	0.375 (0.53)	0.365 (0.56)	-	-
Industry Dummy	yes	yes	yes	yes	yes	-	-
Mean Efficiency	0.14	0.525	0.503	0.60	0.523	0.58	0.63
ME of Technical change[1)]	-	-	-	-	-	0.12	0.098
No. Obs.	169	243	223	192	163	990	740

Note: ***, ** and * significant at 1%, 5% and 10% respectively. The marginal effect of technical change can be estimated by taking the derivative of equation (9) with respect to time and evaluate it at the geometric mean of respective variables.

Table 7: Fixed Effects Panel Data Frontier Estimation of the Translog Production Function. Agriculture and Construction Sector.

Production	Fixed Effects Agriculture Sector		Fixed Effects Construction Sector	
	Unbalanced Panel	Balanced Panel	Unbalanced Panel	Balanced Panel
Constant	0.146*** (5.78)	0.318*** (4.90)	0.218*** (5.21)	0.21*** (2.58)
LnK	-0.115 (-0.49)	-0.597** (-2.32)	0.109 (0.46)	0.372 (0.55)
LnL	1.129* (1.39)	-0.922 (-0.87)	1.9*** (4.07)	1.27* (1.45)
LnK2	0.027 (0.98)	0.003 (0.06)	0.022 (1.15)	0.06* (1.52)
LnL2	-0.076 (-0.62)	0.087 (0.50)	-0.048 (-0.57)	0.080 (0.49)
LnK*LnL	-0.003 (-0.02)	0.168 (1.04)	-0.069 (-0.93)	-0.21* (-1.46)
Time Trend (T)	0.492*** (3.48)	0.342** (2.19)	0.367*** (2.37)	-0.093 (-0.34)
T*LnK	-0.018 (-0.60)	0.065** (1.90)	0.018 (0.82)	-0.039 (-1.01)
T*LnL	0.001 (0.03)	-0.079* (-1.51)	-0.055* (-1.41)	0.087 (0.99)
Time Trend squared (T2)	-0.052*** (-3.21)	-0.06*** (-3.04)	-0.034** (-2.22)	0.002 (0.09)
Constant	-2.456*** (-4.20)	-0.069 (-0.20)	-1.55* (-1.62)	-1.45* (-1.57)
Dummy Foreign$_{t-1}$	-2.373** (-2.25)	-0.270 (-0.34)	1.078 (1.11)	0.309 (0.33)
Dummy Manager$_{t-1}$	-2.070** (-2.18)	-0.503 (-1.06)	-0.720 (-1.21)	-0.540 (-0.79)
DummyDomestic$_{t-1}$	1.116** (2.30)	0.348* (1.32)	-2.657** (-2.12)	-2.035* (-1.33)
Dummy State$_{t-1}$	0.003 (0.009)	-0.510 (-0.92)	-2.84*** (-2.46)	-2.67** (-2.02)
Firm Size$_{t-1}$	-0.134 (-0.15)	0.284 (0.41)	-1.14*** (-2.37)	-0.97*** (-2.36)
Avg. Labor Cost$_{t-1}$	-0.006 (-0.27)	0.014 (0.75)	0.024** (1.86)	0.010 (0.61)
Invest/Sales $_{t-1}$	-4.723*** (-3.15)	0.169 (0.17)	-1.93** (-2.00)	-2.068** (-2.28)
Export/Sales $_{t-1}$	0.959 (0.69)	0.846 (0.80)	5.73** (2.18)	5.002** (2.22)
Dummy SBC $_{t-1}$	1.33** (2.10)	-0.532 (-0.97)	0.244 (0.51)	-0.231 (-0.36)
Herfindahl (3digit)	-0.580 (-0.55)	1.348 (0.83)	0.336 (0.34)	-1.128 (-0.94)
Age of Privatization	-0.713*** (-2.47)	0.092 (0.13)	0.017 (0.09)	-0.504* (-1.44)
Time Trend	1.472*** (4.23)	0.092 (0.13)	0.4* (1.46)	0.88** (1.91)
Mean Efficiency	0.75	0.62	0.70	0.74
ME of Technical change[1)]	0.477	0.337	0.349	-0.0914
No. Obs.	156	100	219	120

Note: ***, ** and * significant at 1%, 5% and 10% respectively. [1)] The marginal effect of technical change can be estimated by taking the derivative of equation (9) with respect to time and evaluate it at the geometric mean of respective variables.

Table 8: Input Elasticities and Returns to Scale.

Manufacturing	**95**	**96**	**97**	**98**	**99**	**Unbalanced**	**Balanced**
Capital Elasticity	-0.0325*** (0.0066)	0.143*** (0.0302)	0.058** (0.02955)	0.24*** (0.006)	0.231*** (0.022)	0.053*** (0.0067)	0.158*** (0.012)
Labor Elasticity	1.104*** (0.401)	0.765*** (0.2853)	0.695*** (0.2052)	0.63** (0.2848)	0.684** (0.344)	0.72*** (0.11)	0.715*** (0.146)
Returns to Scale	1.0715 (0.399)	0.908 (0.2942)	0.753 (0.1954)	0.87 (0.287)	0.915 (0.3384)	0.773 (0.207)	0.873 (0.143)
Test Statistic H_0: RTS=1	0.18	-0.313	-1.26	-0.47	-0.25	-1.09	-0.89
Decision	Accept H_0 CRS	Accept H_0 CRS	Accept H_0 CRS	Accept H_0 CRS	Accept H_0 CRS	Accept H_0 CRS	Accept H_0 CRS

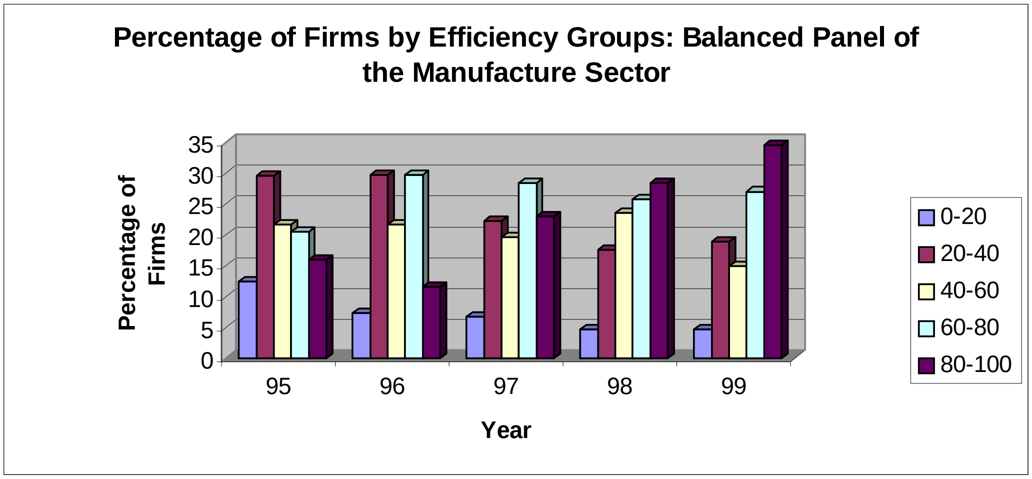
Note: ***, ** , * significant at 1%, 5% and 10% respectively.
Standard errors in parenthesis

Table 8 continued

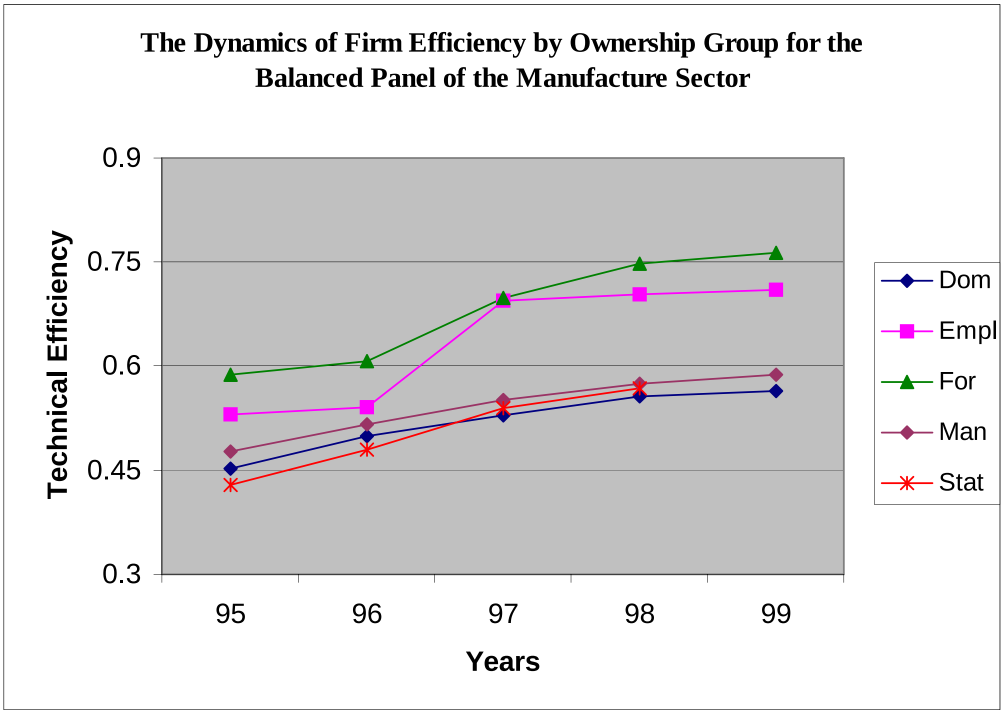
	Agriculture		**Construction**	
	Unbalanced	**Balanced**	**Unbalanced**	**Balanced**
Capital Elasticity	0.55*** (0.07)	0.326*** (0.084)	0.177*** (0.0084)	0.192 (0.19)
Labor Elasticity	0.49* (0.34)	0.655* (0.46)	0.912** (0.453)	0.77*** (0.29)
Returns to Scale	1.04 (0.38)	0.981 (0.857)	1.09 (0.45)	0.962 (0.22)
Test Statistic H0: RTS=1	0.11	-0.022	0.2	-0.17
Decision	Accept H_0 CRS	Accept H_0 CRS	Accept H_0 CRS	Accept H_0 CRS

Note: ***, ** , * significant at 1%, 5% and 10% respectively.
Standard errors in parenthesis

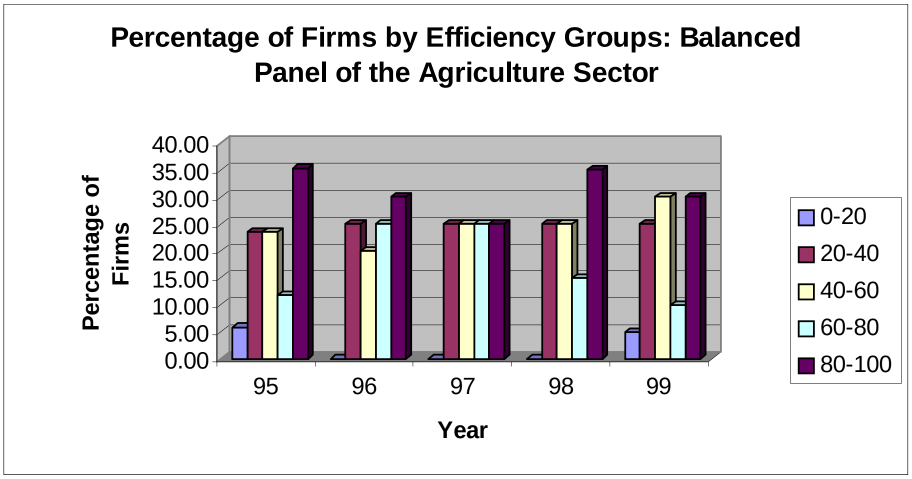
Graph 1



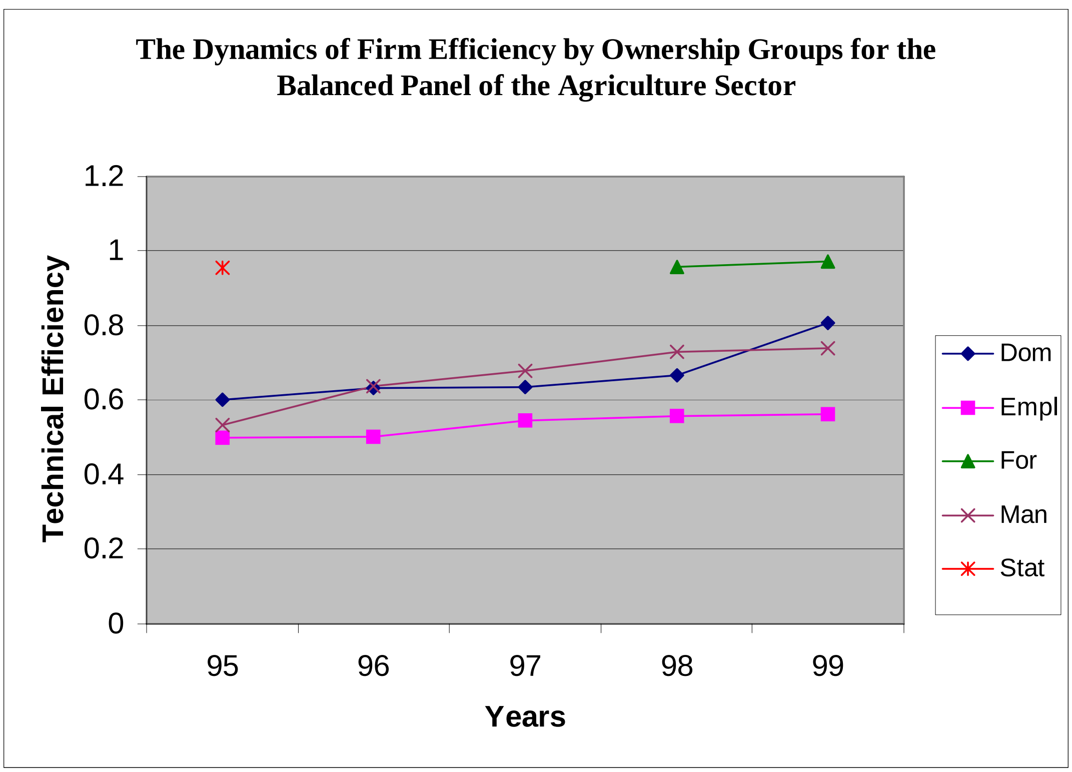
Graph 2



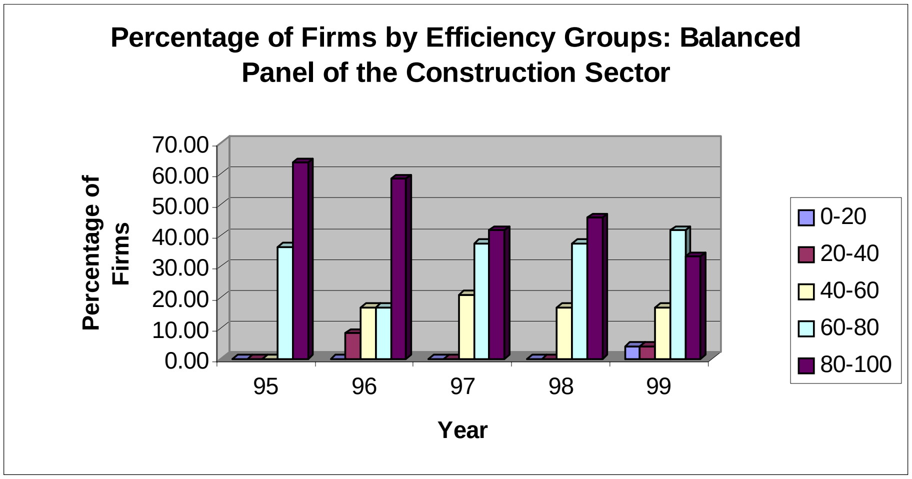
Graph 3



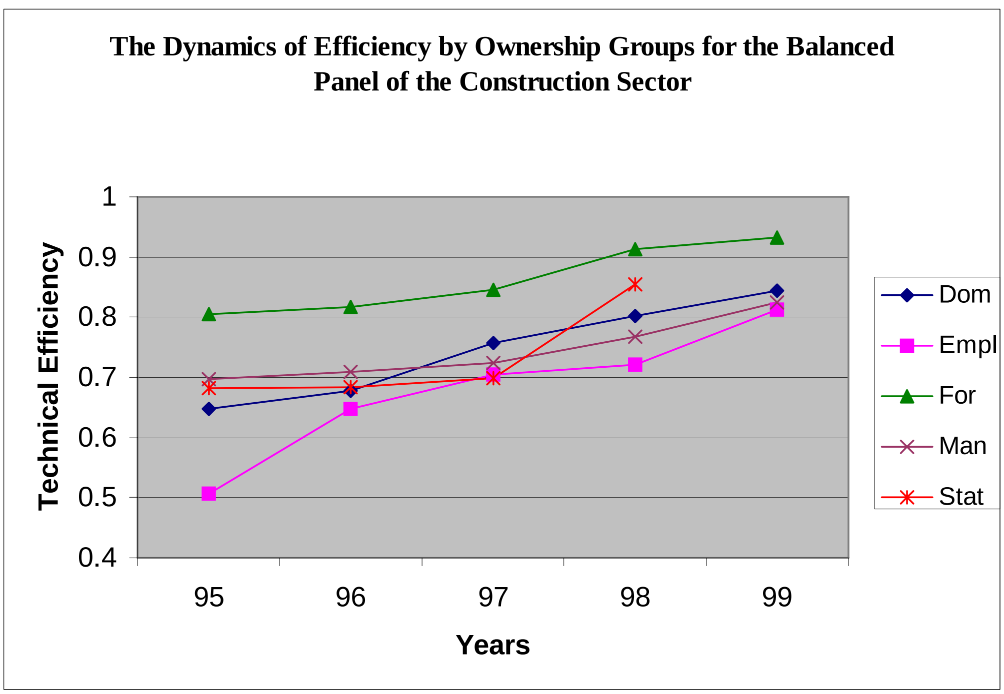
Graph 4



Graph 5



Graph 6



[i] In their study of Russia, Earle, Estrin and Leschenko (1996) point out many cases of insider buyouts at very favorable prices even before the official state privatization program.

[ii] However, it has been observed that soft budget constraints distort the effect of competitive pressure on firm performance (Schafer, 1998; Coricelli and Djankov, 2001).

[iii]We check for inconsistencies using different criteria. For instance, a firm's capital at the beginning and end of each year should be positive; sales should be positive; labor cost in a given year should be positive; average employment per year should be positive and equal or greater than 10; investment in new machines and equipment should be non-negative; and the ownership shares should add up to 100. This leads to a drop of about 10% of observations, resulting in 3578 observations. Furthermore, one of the main weaknesses of the stochastic frontier approach is the presence of outliers, which push the frontier up for all the firms in the sample, causing pronounced firm inefficiency. Therefore, before carrying out the analysis, we perform a series of checks for outliers in the following variables: capital stock, employment, wages and salaries, sales and value added. These consistency checks reveal that eighteen observations belonging to 6 firms are outliers. For these observations employment, capital or sales are more than four times that of the sample average. Consequently, they are dropped from the initial sample. Finally, since we estimate the frontier for three main economic sectors, namely, agriculture, manufacturing and construction, the final number of observations in the analysis is 2174.

[iv] Our measure of soft budget constraint suffers from two further pitfalls. First, it might fail to capture firms with genuine soft budget constraints. More specifically, a firm with negative earnings and zero net financing in a given period is still experiencing soft budget constraint if it expects to receive financing in the future. This measure of soft budget constraint, however, involves unobservables and it will always fail to capture the true degree of soft budget constraint. Second, our measure of soft budget constraint might mistakenly classify as firms that experience soft budget constraints those firms that in fact do not. For example, it could well be the case that young or newly established firms might be loss-making during the first years of their existence until they gain market share and establish relations with financial institutions. In the meantime, they might be receiving outside financing in response to their long-term growth potential. Again, this involves unobservables and as such it is not possible to account for using accounting data. Both these problems generate biases in the real number of firms that experience soft budget constraints, and as such, should be kept in mind in the interpretation of results.

[v] Another technique that estimates firm efficiency is the data envelopment analysis (DEA). This is a non-parametric programming technique. The advantage of DEA is that one need not specify any distributional form for the inefficiency term and for the functional form of the production function. The disadvantage is that it does not account for noise and hence any departure from the frontier is inefficiency. Therefore, this model produces inefficiency scores that are particularly large compared to other frontier models. This assumption is difficult to sustain at the firm level in the presence of measurement error, missing variables and uncontrollable environment factors that can affect production such as the weather. In this paper we pursue the stochastic frontier approach for several reasons. First, this estimation strategy is more likely to be appropriate for transition and developing economies, where the data is heavily influenced by measurement error in the sectors we investigate (agriculture, manufacturing and construction) where the data is also heavily influenced by variables such as weather and disease. Second, we use a data set that is large enough to justifiy the use of parametric estimations. Third, we are also interested in knowing what firm and industry characteristics affect firm level efficiency and the stochastic frontier allows us to do this in a simultaneous estimation. Finally, it allows us to perform tests of hypotheses concerning the existence of inefficiencies, the structure of the production technology and economies of scale.

[vi] A firm's total inefficiency is composed of allocative and technical inefficiency. Estimating total inefficiency would require data on output and input prices. Unfortunately the data we used in the analysis does not provide information on output and input prices. Therefore, we are able to estimate technical inefficiency only.

[vii] A similar approach is followed by Piesse and Thirtle (2000).

[viii] A problem is that u_{it} is unobservable, hence its prediction is needed. The best predictor for u_{it} is the conditional expectation of u_{it} given the value of $e_{it}=v_{it}-u_{it}$ (Jondrow, Lovell, Materov and Schmidt, 1982).

[ix] The likelihood ratio test statistic is $\lambda = -2\{\log(likelihood(H_0)) - \log(likelihood(H_1))\}$. It has a χ_k^2 distribution where k is the number of parameters assumed to be zero in the null hypothesis. Log likelihoods needed to construct the test statistics are estimated from the Frontier 4.1 program as part of the frontier output (see Coelli, Battese and Rao, 1998).

[x] The literature uses interchangeably two terms, endogeneity and selection bias. Nevertheless, they are both used in the same context i.e., the best firms were given out for privatization and that informed and/or powerful groups of potential owners privatized these firms.

[xi] A different strategy followed in a previous version of the paper was to instrument the current ownership structure with its predicted values obtained from a probit estimation. Firm level characteristics such as firm size, its capital intensity, labor productivity, labor quality and a lag of firms' ownership structure were used to predict firms' current ownership structure. The results obtained, showed that the dynamics of efficiency, for instance, for

the manufacturing sector, was almost identical to the one reported in this paper (graph 2). The dangers of this approach, however, as Angrist and Krueger (2001) have pointed out, are that unless the first stage nonlinear equation happens to be exactly specified, the use of its predicted values in the second stage will lead to misspecification bias. This graph is available upon request.

[xii] Further evidence on these issues is provided in Kalmi (2002).

[xiii] According to the Estonian Technology Agency 2002 these industries have the highest innovation expenditure intensity.