Intangible investment and technical efficiency: The case of software-intensive manufacturing firms in Turkey

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The Case of Software-Intensive Manufacturing Firms in Turkey[1]

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Abstract. *This chapter analyzes the effect of intangible investment on firm efficiency with an emphasis on its software component. Stochastic production frontier approach is used to simultaneously estimate the production function and the determinants of technical efficiency in the software intensive manufacturing firms in Turkey for the period 2003-2007. Firms are classified based on the technology group. High technology and low technology firms are estimated separately in order to reveal differentials in their firm efficiency. The results show that the effect of software investment on firm efficiency is larger in high technology firms which operate in areas such as chemicals, electricity, and machinery as compared to that of the low technology firms which operate in areas such as textiles, food, paper, and unclassified manufacturing. Further, among the high technology firms, the effect of the software investment is smaller than the effect of research and development personnel expenditure. This result shows that the presence of R&D personnel is more important than the software investment for software intensive manufacturing firms in Turkey.*

Keywords: Intangible assets, Software investment, Efficiency, Software intensive firms, Stochastic frontier analysis, Production Function, Firms, Turkey.

JEL Classification: L21; L22; L23; L25

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INTRODUCTION

In recent years, the share of investment in intangible assets of the firms in manufacturing industries increased in most of the EU countries while the share of investment in tangible capital has decreased (Corrado,Haskel, Jona-Lasinio & Iommi, 2013). Intangible investment is defined as "the claims on future benefits that do not have a physical or financial embodiment"(Lev,2000). Many authors proposed different ways of classifying the intangible assets (van Ark & Piatkowski, 2004; Young,1998; Vosselman,1998; MERITUM, 2002; Oliner, Sichel & Stiroh, 2008; Hulten & Hao, 2008; Cummins, 2005). A more recent classification is proposed by Corrado, Hulten & Sichel (2009). According to him, there are three main components of intangibles. These are computerized information, scientific and creative property, and economic competencies. The computer software and computerized databases are in the first group. The second group includes science and engineering R&D, mineral exploration, copyrights and license costs, and other activities for product development such as design and research. The third group emphasizes the "soft" part of the intangible assets, such as brand equity, firm specific human capital, and organizational structure.

Studies that focus on the link between intangible investments and productivity found that intangible investments increase the productivity (Oliner et al. 2008; Corrado et al. 2009, Bosworth &Triplett, 2000; van Ark, Hao, Corrado & Hulten, 2009; Park & Ginarte, 1997). However, there is little evidence on the effect of intangible investments on firm efficiency (Becchetti, Bedoya & Paganetto, 2003). In this chapter, we analyze the effects of software investment and R&D personnel expenditure which are components of intangible investment on firm efficiency in Turkey. We consider the software intensive manufacturing firms in Turkey for the period 2003-2007. We observed two main trends. First, the number of firms making software investment decreased during the period investigated. Second, firms which already make software investment became more software-intensive. The main question asked is the increase in the intensity of software investment results in efficiency gains for the Turkish manufacturing firms. We also included R&D personel expenditure as another component of intangible investment in this chapter.

This chapter is organized as follows: Background section provides the review of literature on intangible investment of the firms. Model section explains the specifications of the production function and the technical efficiency. In this chapter, we also provide an extant review of literature on determinants of technical efficiency. The other section is devoted to data and methodology. We, then discuss empirical results. The last section introduces concluding remarks.

BACKGROUND

The 1970s marks the beginning of a period referred to as post-Fordist Era. This period is characterized with a transition from manufacturing based economy to services based economy. This change has resulted in a shift from tangible assets such as physical, financial, and human to the intangible ones in the production process (Shapiro & Varian, 2013). The history of the concept of intangible investment dates back to Machlup (1962). He conceived the knowledge as an intangible asset and emphasized the difficulties in isolating the effects of intangible investment on the knowledge producing industries. Therefore, the much of the concern with the intangible asset is related to their identification and the measurement.

Intangible investment refers to investment in human capital such as education and socialization activities (Webster,1999). Adams & Oleksak (2010) consider the intangible assets such as the personal networks, reputation, or innovation capability and refer to them as “invisible assets”. More recently, the definition of intangible assets is broadened to include software and databases, research and development activities, intellectual property rights, human capital, and organizational structure.

Empirical studies that use intangible investment as a production factor increased since the 2000s. Jalava & Pohjola (2008) found the positive effect of intangible investment on Finnish economy by using non-financial business sector data and emphasized the increasing role of the quality of the investment rather than the quantity in the economic growth. The positive effect of intangible investment on economic growth is also observed in cross country studies. Van ark et al.(2009) used the computerized information, innovative property, and economic competencies to proxy the intangibles and found that the combined effect of these variables accounts for a quarter of labour productivity growth in the US and several countries in the EU. Park & Ginarte(1997) analyzed another component of the intangibles, namely intellectual property rights (IPRs). They found that IPRs directly affect inputs such as research and development expenditure and physical capital.

Other components of intangible investments received considerable attention in the literature. The software investment as productive asset was not considered often (Basu & Fernald, 2007). In recent years, this component became capitalized as an expenditure in order to observe its contribution to GDP. According to Borgo, Goodridge, Haskel & Pesole (2013) asset training, design, and software have the largest shares in knowledge spending especially in the services sector in UK, while R&D has only a small share. Further, Becchetti et al. (2003) found that software investment has a complementary effect on skilled labour and increases both labour productivity and the firm efficiency. When ICT is considered as a general purpose factor, ICT investment could also facilitate firm efficiency. Castiglione & Infante (2014) have observed that positive effect of ICT on technical efficiency of Italian firms manufacturing firms during the period 1995-2006. The effect of ICT on technical efficiency is much stronger for the firms that make changes in their organizational structure, that invest in research and development and that are open to international markets. In a similar vein, Dimelis & Papaioannou (2014) examined the diffusion of ICT in manufacturing and services sectors in EU for the period 1995-2005. In their study, ICT variable is decomposed into three factors such as computing equipment, communications' equipment, and software. They found that software and communications equipment have a strong negative effect on technical efficiency and this effect remain robust after controlling the degree of market regulation. Further, Berghall (2014) have found that new ICT technologies improve the performance of Finnish industries that lag behind the frontier. When industry and time effects are controlled for, ICT has a significant effect on technical efficiency during the period 1986-2003 in Finnish industry.

MODEL

We use stochastic production frontier approach to simultaneously estimate the production function and the determinants of technical efficiency. The stochastic frontier model with panel data specification is given by

$$y_{it} = \alpha + \sum \beta_x x_{kit} + \varepsilon_{it} \quad (1)$$

$$\varepsilon_{it} = V_{it} - U_{it} \quad (2)$$

$$t = 1, ..., T \qquad i = 1, 2, ..., N$$

$$U_{it} \geq 0 \quad (3)$$

Where y_{it} and x_{kit} are the output and the vector of inputs of firm i at time t. β is the vector of unknown parameters, V_{it} and U_{it} are independent, unobservable random variables. Accordingly, V_{it} indicates statistical noise which is normally distributed with mean zero and variance σ_v^2 and the σ_u^2. U_{it} is the non-negative random variable associated with technical inefficiency and it is allowed to vary over time. U_{it} can be described as:

$$U_{it} = \left\{\exp\left[-n(t-T)\right]\right\} U_{it} \qquad (4)$$

Where n_{it} is an unknown parameter to be estimated and U_{it} are independent and identically distributed non-negative random variables.

Production Function

In this study, four types of variables are used to estimate production function which is in translog form. These are capital, labor, raw material, and energy. Table 6 displays the variable definitions.

$$\begin{aligned}\ln Y_{it} &= \beta_0 + \beta_1 t + \beta_2 t^2 \beta_3 \ln(K_{it}) + \beta_4 \ln(L_{it}) + \beta_5 \ln(RM_{it}) + \beta_6 \ln(E_{it}) + \beta_7 \ln(K_{it})^2 + \beta_8 \ln(E_{it})^2 + \beta_9 \ln(L_{it})^2 + \beta_{10} \ln(RM_{it})^2 \\ &+ \beta_{11} \ln(K_{it}) \ln(L_{it}) + \beta_{12} \ln(K_{it}) \ln(RM_{it}) + \beta_{13} \ln(K_{it}) \ln(E_{it}) + \beta_{14} \ln(L_{it}) \ln(RM_{it}) + \beta_{15} \ln(L_{it}) \ln(E_{it}) + \beta_{16} \ln(RM_{it}) \ln(E_{it}) \\ &+ \beta_{17} \ln(K_{it}) t + \beta_{18} \ln(E_{it}) t + \beta_{19} \ln(RM_{it}) t + \beta_{20} \ln(L_{it}) t + v_{it} - u_{it}\end{aligned}$$

$$t = 1, \ldots, T \quad i = 1, \ldots, N \qquad (5)$$

Where Y_{it} is the real output firm i in year t, K_{it} is the capital stock measured by depreciation allowances in year t, E_{it} is the electricity and fuel purchased by firm i in year t, RM_{it} is the total value of intermediate goods used in the production of inputs by firm i in year t. Time variable indicates technological change. v_{it} indicates random errors that are independently and identically distributed with $N(0, \sigma_v^2)$ and u_{it} represents technical inefficiency term following normal distribution with mean μ_{it} and variance σ_u^2.

Capital stock variable is created based on the Perpetual Inventory Method (PIM). In the Eq.(6) below, K_t represents the capitak stock at time t. K_{t-1} indicates initial capital stock, d shows the depreciation rate and I_t is the investment. Initial capital stock is calculated assuming that there exists permanent growth at the sum of the industrial rate of growth and the rate of depreciation.

$$K_t = (1-d)K_{t-1} + I_t \quad (6)$$

Nominal values of capital stocks are deflated by the corresponding sectoral producer price indices at four digit. All variables in the production function are in the logarithmic form.

Technical Efficiency Function

Technical efficiency is defined as the distance of a firm from an efficient frontier (Battese & Coelli, 1992). The efficiency of a firm consists of two components: technical efficiency and allocative efficiency (Farrel, 1957). Technical efficiency indicates the ability of a firm to obtain maximum output from a given set of inputs. A more specific definition belongs to Koopmans (1951). Accordingly, a producer can be considered as technically efficient if the increase in the output is achieved by the reduction in at least one other output or increase in at least one input.

In this study, the inefficiency model is formed by including a list of explanatory variables that are classified as firm specific variables in order to explain the firm efficiency denoted by μ_{it}.

$$\mu_{it} = \delta_0 + \delta_1 Tradeopenness + \delta_2 Outsourcing / Subcontracting + \delta_3 RegionalAgglomeration + \delta_4 R\&DPersonnel + \delta_5 SoftwareInvestment + \delta_6 TimeEffects + \delta_7 SectorDummies \quad (7)$$

In Eq. (7), δ_0 is the constant term which represents differences in production that cannot be explained by firm specific variables. Trade openness is measured as the share of total products and services exports to total revenues. Outsourcing is measured at two levels. The first one is outsourcing expenditure which is defined as the share of outsourcing expenditure to total expenditure. The second one is the outsourcing revenue which is measured by the share of outsourcing revenues to total revenues. We added outsourcing revenue, subcontracting expenditure and government subsidy in the estimation of low technology firms[i]. Subcontracting expenditure is measured by the share of subcontracting expenditure to total expenditure. Subsidy is a dummy variable that takes the value of 1 if firm received subsidy between 2003-2007. Regional agglomeration is measured as the share of the firm's revenues to the total revenue of the region. Research and development (R&D) personnel is measured by dummy variable which takes the value of 1 if the firm invests in R&D personnel expenditure and 0 otherwise. This variable is selected due to the importance of qualified personnel for firms making software investment. Software investment is measured as the share of software investment in total intangible investment. Year and sector dummies are also included in the study in order to control for heterogeneity.

EMPIRICAL LITERATURE ON DETERMINANTS OF TECHNICAL EFFICIENCY

There is an extensive literature on the determinants of technical efficiency (see, Table 1). In this study, we focus on a part of those variables such as trade openness, outsourcing, government subsidy, regional agglomeration, R&D personnel, and software investment. Adding year effect is considered to be relevant because the time period in this study corresponds to the period of privatization in Turkish telecommunication sector. Following sections deal with the determinants of technical efficiency of Turkish software intensive manufacturing firms.

Trade Openness

One of the determinants of technical efficiency is trade openness which indicates the exporting activities of the firm. Production efficiency of firms that compete in international market could be high because competition forces firms to allocate resources more efficiently, to exploit scale economies, and to improve their technology (Balassa,1978; Feder,1983; Ram,1985; Bodman,1996).

The positive effect of export on firm efficiency is found by Aw & Batra,1998; Sun, Hone & Doucouliago,1999; Piesse & Thirtle, 2000; Gumbau-Albert & Maudos,2002; Delgado, Farinas & Ruano, 2002, Hossain & Karunaratne,2004. Negative effect is found by (Grether,1999) or no relation is observed by (Alvarez & Crespi,2003). Trade openness of the economy explains regional and industrial variation in terms of efficiency in the case of China (Sun et al., 1999). Economic reforms in China after 1980 targeted coastal regions, therefore, the economy in those regions became much exposed to foreign trade that results in efficiency gains. For the Canadian manufacturing sector, both import penetration and export share increased in the period of 1973-1992. Those years were also marked by the reduction in protection under the North American Free Trade Agreement (NAFTA). This generated two main effects on Canadian manufacturing firms. The first was to lose tariff protection on some goods. The second was to gain tariff-free access to international product markets. The ultimate effect of openness to international competition decreased inefficiency of Canadian manufacturing firms (Bodman, 1996). In Taiwan, exporting activities had positive effect on the productivity of the small and localized firms which did not invest in a specific technology (Aw & Batra, 1998). This result indicates that there are some unobservable factors such as managerial ability of the small firms that provide efficiency gains.

The effect of the export share on technical efficiency of the firm, on the other hand, increases at a decreasing rate and reaches a maximum point in Bangladesh (Hossain & Karunaratne, 2004). When the export share is interacted with non-production labor, the positive effect of export share becomes negative (Grether,1999). The reason for negative effect of exports on efficiency could be explained by technological disparities between domestic firms and foreign counterparts.

Outsourcing

Outsourcing is taken as another determinant of technical efficiency which indicates all subcontracting relations between firms including hiring temporary labor. Transaction cost approach elaborates the outsourcing activities in terms of cost reduction functionality (Williamson, 1973). Firms can either outsource production activities or business related services. Therefore, they can allocate the resources to the activities which provide comparative advantage. As a result, firm can attract more highly skilled staff through investment in its core competences.

Some part of the literature concerns with the effect of outsourcing on profitability and productivity because outsourcing could produce significant differences in the quality of final products and sales even if there is no change in the efficiency[ii] (Görzig & Stephan, 2002; Lacity & Wilcocks, 1998; Gianelle & Tattara, 2009). In addition, the long term and short term effect of outsourcing could be different from each other. Windrum, Reinstaller & Bull (2009) argued that in the long term, productivity of outsourcing firms decreases.

The effect of outsourcing on firm efficiency is studied by Heshmati, 2003; Taymaz & Saatçi, 1997. They found the positive effect of outsourcing on firm efficiency. In fact, the effect of outsourcing depends on the content of the outsourced activity. If non-productive activities are outsourced, the effect of outsourcing on efficiency could be positive since outsourcing decrease the costs of production. In addition, firm became much focused on the core fields which results in increase in quality of the products. However, if there is a mismatch between outsourcing firm and the external supplier in terms of organization of the work, problems could emerge based on the quality concerns.

Government Subsidy

Firms in the developing countries mostly struggle with financial difficulties to sustain themselves. Public subsidy programmes are developed to support those firms. In recent years, this mechanism has become conditional on implementing innovative activities such as producing a new product or a process.

The relation between subsidy and the firm efficiency could be negative. This implies that subsidized firms are less efficient than their non-subsidized counterparts (Martin, John & Page, 1983). Accordingly, government regulation which targets to reduce input and output prices, encourages rent–seeking behaviour among entrepreneurs. In some cases, subsidies go to firms that already conduct R&D activities[iii], therefore, the positive effect of subsidy on decision to innovate is not clearcut (González, Jaumandreu & Pazo, 2005). In this study, the term subsidy is only included in the estimation of low technology manufacturing firms since a considerable number of firms in this group are subsidized by the government.

Subcontracting

Subcontracting and outsourcing activities can be considered similar to each other. Both of them reflects the provision of services by the external vendors. As for the case of subcontracting, firm may have the required facilities to operate the activities but it prefers to subcontract them. For the case of outsourcing, firm does not have in house production capability of the activity and it depends on the external supplier (Van Mieghem, 1999).

Several studies analyzed the effect of subcontracting on the firm efficiency. The positive effect of subcontracting on technical efficiency is conditional on the emergence of network effects as a result of subcontracting activity (Aoki, 1989; Lazonick, 1990; Burki &Terrel, 1998,Taymaz & Saatci, 1997).

Regional Agglomeration

Firms making software investment are included in this study. Although it could be ambigious to classify them as "software firms", allocating resources into the software component of the information and communication technologies (ICT) is an indication of innovativeness (Bessen & Hunt, 2007). Therefore, the effect of location could be analyzed in this frame. Geographical proximity could facilitate technological improvement, competitiveness, market linkages and collaboration among firms through such mechanisms as trust (Romijn & Albaladejo, 2002).Tacit knowledge[iv] is facilitated by the trust between firms in the same location. This situation eases the knowledge transfers from one organization to another. The close interaction among firms clustered in a specific geography reduces the risk and uncertainty towards adopting a new technology decreases.

Taking those considerations into account, expected effect of regional agglomeration on efficiency is positive (Driffield & Munday,2001;Taymaz & Saatçi,1997). On the other hand, efficiency benefits could decrease after some point that cities reach a certain population (Mitra,1999). As the communication costs decline and the quality of interaction with the partners outside the region increases, the positive effect of geographical proximity could dissappear (Curran & Blackburn,1994).

R&D Personnel

In the efficiency literature, the effect of research and development (R&D) activities are analyzed by using various proxies such as R&D capital intensity (Kumbhakar, Ortega-Argiles, Potters, Vivarelli & Voigt, 2012) R&D capital stock (Wang, 2007), or R&D expenditure (Perelman, 1995).

Regardless of how it is measured, R&D activities are intangible assets carrying the notion of creative property. Therefore, the presence of R&D personnel which reflects the absorptive capacity of the firm (Cohen & Levinthal,1989) is crucial especially for firms operating in the capital intensive industries such as electiricity, machinery, and chemicals. Based on this, the positive effect is expected for this variable (Dilling-Hansen, Madsen & Smith, 2003; Griliches,1998; Coe, Helpman & Hoffmaister, 1995; Tassey,1997; Huang &

Liu,1994). There could be long term and short term effect of R&D activities. Dilling-Hansen et al. (2003) emphasized that when the R&D activities of the firms are based on basic research, its effect on firm performance emerges in the long run.

Software Investment

The effect of intangible investment on productivity has been studied only recently. Most of the evidence belongs to developed countries (Corrado et al. 2013). To consider the effect of ICT on productivity, the positive effect of computer networks is found (Atrostic & Nguyen, 2005). As for the comparison between US and Japan in terms of the effect of computer networks, Japan lags behind the US. One possible reason is that complementary activities such as innovation or process change is lower in Japan (Atrostic, Motohashi & Nguyen, 2008). In addition, complementarity could exist among the ICT components such as the relation between information networks and business networks (Motohashi, 2007).

The effect of intangibles on economic growth or productivity in developing countries was not investigated due to lack of data. In this study, we analyze the effect software component of intangible investment on Turkish manufacturing firms for the years between 2003-2007 by using information on software investment. In those years, there has been an increase in the software investment intensity while there is no increase in the number of firms that make that investment.

The motivation for using this variable is to investigate whether investing in software component of ICT generates differential effect on the efficiency among software-intensive firms. There are several studies on the effect of ICT (see, Table 2). Empirical evidence establishes a positive link between ICT and technical efficiency (Brasini & Freo, 2012; Castiglione,2012; Castiglione & Infante, 2014; Dimelis & Papaioannou, 2010; Berghall, 2014; Bechetti et al.2003; Lee & Barua,1999; Romero & Rodriguez, 2010; Repkine,2008; Bertschek, Fryges & Kaiser, 2006; Criscuolo & Waldron, 2003; Rincon, Robinson & Vecchi, 2005). Milana & Zeli (2002) and Repkine (2009) have found no significant effect of ICT on firm efficiency. Accordingly, ICT may not change the technology frontier for countries having a high level of telecommunication investment.

Time Effects

Reforms in the telecommunication sector on a global scale were started in 1980s. Those reforms include the directions such as commercialization of the telecom services, involvement of private firms in the telecommunications sector, diversification in the service supply, competition enhancing, and the elimination of government from the ownership status (Wellenius & Stern, 1994). The United States and the United Kingdom are the two countries that initiated the liberalization process in the telecommunications sector. British Telecom was privatized by the act of Telecommunications in 1984 and the Office of Telecommunications (Oftel), which was publicly funded and independent agency, was established as a regulator of the sector. In the same year, under the state antimonopoly ruling, AT&T, the largest American telecommunications company, was broken up into 7 regional companies. For both countries, the main motivation was to encourage competition in the sector. The UK Government chose the duopoly policy because the presence of lots of competitors in the sector might result in failure of the sector (Gabel & Pollard, 1995). Therefore, Mercury Communications obtained license as a first competitor for the British Telecom.

In the following years, privatization in the telecommunications sector spread throughout the developing countries. The first move in the liberalization of telephony services in Turkey dates back to 1994 when the Telsim and Turkcell operators made an agreement with Telecom based on the revenue sharing and few years later, in 1998, they obtained the licenses. By the end of 2003, the monopoly rights of the Turkish Telecom have abolished which started the privatization process in the telecommunication sector. In the following years, competition has become higher in mobile sector relative to fixed telephony or broadband (Atiyas, 2011). We introduce year dummies for this period in order to investigate the effect of privatization on efficiency in software-intensive firms for the years between 2003-2007.

Some writers consider that the creation of the competitive environment with the privatization of the state monopoly enhances productive efficiency (Jha & Majumdar, 1999; Ross, Beath & Goodhue, 1996; Bortolotti, D'Souza, Fantini & Megginson, 2002, Lam & Shiu, 2010). From the economic development perspective, the main issue is based on whether privatization generates inequity while it increases efficiency. Birdshall & Nellis (2003) state that it is possible to increase efficiency without decreasing equity. For countries that experienced inefficiency and inequality in the distribution of the services, conditions of failure in privatization were introduced in pre-privatization period such as mismanagement of the privatization or low technical infrastructure.

DATA AND METHODOLOGY

In this study, five waves of the Structural Business Statistics of Turkey administered by Turkish Statisical Institute (TURKSTAT) are used in order to analyze the effect of software investment on firm efficiency. It includes the data from the year 2003 to 2007. The dataset has detailed information on sales, revenues, and costs for each firm. First, 2003-2006 dataset was shared by TURKSTAT then 2007 wave was introduced as a single dataset. Two datasets are merged with the help of the key dataset including the common id numbers for the two waves, 2007 and 2003-2006 dataset. After deleting the duplicated observations, 17131 observations remained for each year[v]. Only manufacturing firms are included in this study, since measuring productivity in services sector is quite different from that of production sectors. There are 45900 manufacturing firms in the dataset.

In this study, capital stock is proxied by depreciation allowances. Some observations of this variable have zero values which indicates that those firms do not have any production activities. Therefore, firms with no information on capital stock in any of the years are removed from the sample. The same procedure is applied to the employment variable. Since firms employing less than 20 workers are sampled, observations for micro firms are deleted. Moreover, manufacturing industry revenues which are used to construct output variable is cleaned of the zero observations. In this study, firms that do not invest in software are excluded. A number of observations are also removed following the construction of the variables. For instance observations which exceed 1 for the variable export share are cleaned of the sample. Therefore the final sample includes 8450 observations.

We use OECD(1997) classification to group firms in terms of their technological sophistication. Accordingly, firms operating in electronics, machinery, and chemicals are high technology firms, while textiles, food, paper are low technology sectors. The distinction between high technology and low technology firms are based on the R&D intensity. High technology sectors are more R&D intensive while low technology industries are conceived as low R&D performers[vi].

In this study, there are 2212 observations for the high technology firms. The number of observations for low technology sectors are 4160. We aim to compare the effect of production function variables and the effect of determinants of technical efficiency. For this purpose, we discuss the estimation results for high technology and low technology separately.

As for the methodology, stochastic frontier model with time varying efficiency is used in this study. The advantage of using panel data in stochastic frontier production is that inefficiency term and input levels do not have to be independent as cross section models (Schmidt & Sickles, 1984). In addition, there is no need for distribution assumption for the inefficiency effect. We assume the translog functional form since it does not impose any prior restrictions on the production function unlike Cobb Douglas. The appropriateness of translog form is tested by introducing Cobb Douglas for each estimation.

EMPIRICAL RESULTS

Table 3 reports the empirical results of the stochastic frontier and the determinants of technical efficiency in high technology manufacturing firms for the period 2003-2007. High technology manufacturing sectors are named as "capital intensive sectors". Table 4 shows the empirical results of the stochastic frontier and the determinants of technical efficiency in low technology manufacturing firms for the period 2003-2007. All models used in this study have a panel characteristic. The advantage of using panel data in stochastic frontier production is that inefficiency terms and input levels do not have to be independent as in cross section models (Schmidt & Sickles, 1984). In addition, there is no need for distributional assumption for the inefficiency effect. We assume the translog functional form for the technology since it does not impose any prior restrictions on the production function, unlike Cobb Douglas. In addition, for each model, the appropriateness of the translog form is tested by introducing Cobb Douglas.

Each table is composed of two parts. The first part shows the frontier function variables, which are output, capital stock, labor, raw material, and electricity and fuel. Taking the heterogeneity issue into account, sector dummies are introduced in the production function. The second part shows the inefficiency frontier function variables which are trade openness, outsourcing, regional agglomeration, R&D personel, and software investment. All these explanatory variables display sufficient variation regarding their distribution. This model is time variant production frontier with year dummies that are introduced in both production function and technical efficiency. All variables are in logarithmic form.

Starting with the variables in the frontier function, we expect a positive effect of capital stock on output in high technology manufacturing firms. Therefore, increase in capital intensity indicates the efficient use of machinery which results in overall increase in the firm efficiency. The output increases with capital stock at 14 percent. The positive sign of capital stock squared indicates that the effect of capital stock increases at an increasing rate. As for the low technology manufacturing firms, the effect of capital stock on output is positive and significant but lower than that of high technology sectors. The positive and significant sign of the squared term shows that it increases at an increasing rate.

When the capital stock interacts with labor, raw material, electricity and fuel, the coefficient gives negative, negative, and positive effect, respectively for the high technology manufacturing firms. Interaction with labour is negative and insignificant whereas interaction with raw material is negative and significant. Therefore, the existence of raw material results in a decrease in the effect of capital stock on output. The interaction effect with electricity and fuel, on the contrary, is positive, implying that these two inputs are complementary. As for the low technology manufacturing firms, the interaction with labor, raw material, electricity and fuel gives positive, negative, and positive effect, respectively. Among these, only interaction of capital with the raw material gives significant result. This indicates the same result with the high technology manufacturing firms. However, the coefficient of the interaction term is lower for low technology manufacturing firms.

The effect of labor is also positive and significant with a small coefficient for high technology manufacturing firms. In addition, the labor squared gives zero and insignificant result. Interaction terms with other inputs do not give significant results. In contrast to high technology sectors, labour has a negative effect on output. The positive sign of the squared term of this variable indicates that the effect of labor decreases at an increasing rate.

When the labour variable is interacted with the raw material, electricity and fuel separately, the coefficients are positive for the high technology manufacturing firms. However, those coefficients are not significant. Similar results are obtained for the low technology manufacturing firms.

The coefficient of raw material has the highest share in comparison to other production inputs for the high technology manufacturing firms. The effect of its square term gives positive and significant result indicating that the use of raw material in the production generates increasing effect on output. Examining the interaction of raw material with the other input variables, the interaction with electricity and fuel has a negative and significant effect on output. So, the presence of raw material results in a decrease in the effect of electricity and fuel expenditure. As for the low technology manufacturing firms, the effect of raw material is positive and significant and higher than that for high technology manufacturing firms. Its square is also positive and significant indicating that the effect of raw material on output increases at an increasing rate. The interaction with electricity and fuels negative and significant. This implies the same result with the high technology manufacturing firms.

The sign of electricity and fuel is positive and significant. The positive sign of the squared term of this variable indicates that its effect on output increases at an increasing rate. As for the low technology manufacturing firms, the sign of the electricity and fuel gives positive and significant result and the positive sign of the squared term indicates that it increases at an increasing rate.

The positive and significant effect of the time variable indicates that the mean technical progress is 4 percent per year in high technology industry. When the time interacts with capital stock, labor, raw material, electricity and fuel, the coefficient gives negative, zero, positive, and negative effect, respectively. Among these, only the interaction of time with raw material gives significant result, indicating that technical change is raw material saving. As for the low technology manufacturing firms, the effect of time on output is positive and significant as in the case of high technology sectors. However, the sign of the squared term indicates that its effect decreases at an increasing rate.

Considering the variables in the inefficiency frontier function, we have trade openness, outsourcing, regional agglomeration, R&D personnel, software investment, and year dummies. The effect of trade openness is negative and significant, therefore, exporting activities increase the technical efficiency of the firm. However, its effect is lower than that of low technology sectors. This result indicates that export activities play a much more crucial role in explaining technical efficiency for low technology firms. In 1996, quota restrictions on exporting textile products to EU are abolished with the Customs Union Agreement in Turkey. Export share of the country increased during the period investigated. This result is in line with the cases of China (Sun et al., 1999); Hungary (Piesse &Thirtle, 2000), Spain (Gumbau-Albert & Maudos, 2002), and Chile (Tybout, De Melo & Corbo,1991).

We next consider the effect of outsourcing expenditure on technical efficiency. It has the highest share in the technical efficiency estimation with a negative sign. As for the low technology manufacturing firms, the effect of outsourcing expenditure on efficiency is positive and significant. Its effect is higher than that for the high technology sectors which indicates that outsourcing activities are more important in explaining the technical efficiency in low technology sectors. This result is in line with Heshmati (2003) and Taymaz & Saatci (1997). The positive effect of outsourcing on efficiency could be based on allocation of activities that provide comparative advantage.

The relation between regional agglomeration and technical efficiency is positive. It has the highest coefficiency following the outsourcing expenditure. It is higher than that of low technology firms. This result emphasizes the importance of location in explaining the technical efficiency in high technology sectors (Driffield & Munday, 2001; Taymaz & Saatçi, 1997).

The presence of R&D personnel is also an important determinant of technical efficiency in high technology sectors, implying that R&D intensive firms are more efficient (Cohen &Levinthal, 1989; Coe et al.1995; Huang & Liu,1994). This finding is in line with R&D supporting policy in high technology sectors in Turkey. As for the low technology manufacturing firms, the coefficient of R&D has negative and significant effect on technical inefficiency. On the other hand, its effect is smaller than that of the high technology industry.

The effect of software investment is positive and significant. However, the coefficient is the smallest in comparison to the other variables. This indicates that software investment is still not the main factor in explaining technical efficiency since software investment is quite a new factor of investment. As for the low technology manufacturing firms, software investment has also positive and significant effect on technical efficiency for low technology manufacturing firms.

Time effects are also introduced in the estimation. All of them are positively related to technical efficiency. This result is in line with the assumption that links positive association with the privatization and technical efficiency (Jha & Majumdar, 1999; Ross et al., 1996; Bortolotti et al. 2002; Lam & Shiu, 2010).

For the low technnology manufacturing firms, we included some additional factors such as subsidy, outsourcing revenue, and subcontracting expenditure in the technical inefficiency function. Interestingly subsidy does not appear to be significant for low technology sectors although the considerable number of firms in the low technology sectors are subsidized in Turkey.

It is crucial to make a distinction between outsourcing reveue and outsourcing expenditure. For the first one, outsourcing is the main activitiy of the firm that generates a large part of the turnover while for the second, firm may outsource part of its activities to the external suppliers. We included outsourcing revenue in the efficiency estimation of the low technology manfacturing firms since outsourcing revenue accounts for considerable amount of the firm turnover for that group of firms. Nevertheless they do not have the same degree of impact with outsourcing expenditure. This indicates that firms that do outsource their activities to other firms are more efficient than for firms in which outsourcing is the main activity.

Table 5 displays the test results for the models. The first null hypothesis is based on the presence of Cobb-Douglas functional form, therefore, all squared and interaction terms are excluded from the model. These tests are applied for each technology group. The likelihood ratiosof test statistics are calculated by the formula as

$$-2\{\log[likelihood(H_0)]-\log[likelihood(H_1)]\} \qquad (8)$$

If the value exceeds the 5 % critical value, H_0 is rejected. For this study, it implies that Cobb Douglas is not the appropriate functional form. The second null hypothesis is based on the absence of inefficiency in the model. If the paramater gamma is zero, the variance of the inefficiency effects is zero. This indicates that the model is reduced to traditional response function that include determinants of efficiency into the production function. The test statistics reject this null hypothesis. For high technology industry, a key parameter γ is 0.94. For the low technology industry, this variable is 0.78. This implies that much of the variation in the composite error term is due to the inefficiency component. The third null hypothesis is that firms in the high technology sectors and low technology sectors are fully efficient. When the only gamma is set to zero, it specifies that the inefficiency effects are not stochastic. However, this assumption is rejected in this study.

The forth null hypothesis is that there is no inefficiency effect. When only inefficiency effects are set to zero, it specifies that the inefficiency effects are not a linear function of the inefficiency parameters. This hypothesis is also rejected which indicates that the joint effects of these inefficiencies of production are significant, although individual effects of one or more variables may not be significant.

The fifth null hypothesis is that inefficiency effect is time invariant. As reported in the Table 3 and 4, year dummies give negative and significant results for the technical inefficiency. This implies that the null hypothesis is rejected.

CONCLUSION

The adoption and the use of Information and Communication Technologies (ICTs) are indications of technological progress and important keys for the development of knowledge-based economy and its future sustainability. The existence of ICT infrastructure provides business opportunities and helps firms build up business networks between suppliers, buyers and customers. A large number of business tasks are succeeded through the internet by means of personal computers and external network facilities which, in turn, decrease the transaction costs. Moreover, use of ICTs provides an efficient channel for advertising, marketing and direct distribution of goods and services. ICTs play a dual role in the business world. It is both a technology stock of the firms and a channel for technology transfer from one firm to another (Hsieh & Lin 1998).

ICT have three main components. These are telecommunication investment, hardware investment and software investment. Unlike hardware and telecommunication investment, measuring the software investment is difficult since it is generally supplied with the hardware component. In recent years, a considerable effort has been directed to isolate the effect of software investment as a part of intangible investment on firm efficiency. In Turkey, there has been an increase in the software investment of Turkish manufacturing firms during the period 2003-2007. In this study, we analyzed whether the increase in software investment resulted in efficiency gains for software-intensive manufacturing firms in Turkey by using time varying stochastic frontier approach. The main motivation was to increase output by increasing efficiency with given amounts of resources. Therefore, the term efficiency can be simply defined as the success in producing as large as possible with the given input. Our results show that software investment is crucial both for the high technology and the low technology manufacturing firms. However, its effect is much higher in the high technology sectors such as electricity, chemicals, and machinery as compared to the low technology sectors such as clothing, textiles, food, paper, and unclassified manufacturing.

Despite its positive and significant effect on the firm efficiency, software investment does not generate an effect as large as the research and development personnel which is another component of intangible investment. Software intensive firms mostly rely on the skilled workforce which is competent in research and development activities. This result shows that the presence of R&D personnel has a crucial role for productive efficiency of the manufacturing firms in Turkey.

APPENDICIES

TABLE 1 . A list of Literature on the determinants of firm Efficiency and Expected Signs

Variables	**Expected Sign**	**Motivation**	**Literature**
Trade Openness	+	Small firms with managerial abilities	Aw & Batra (1998)
		Access to foreign market	Sun et al. (1999)
		Learning through exporting	Delgado et al. (2002)
		Greater capacity of utilization International market competition Specialization in production	Piesse &Thirtle (2000); Gumbau-Albert & Maudos(2002); Hossain & Karunaratne (2004)
	-	When combined with non-production labor its effect on the firm efficiency turns out to be negative	Grether(1999)
Outsourcing	+	Allocation of resources to the activities that provide comparative advantage	Heshmati(2003); Taymaz & Saatçi(1997)
Regional Agglomeration	+	Agglomeration effect	Driffield & Munday(2001);Taymaz & Saatçi (1997)
	-	Efficiency benefits could decrease after some point that cities reach a certain population	Mitra(1999)
		As the communication costs decline and the quality of interaction with the partners outside the region increases, the positive effect of geographical proximity could dissappear	Curran & Blackburn (1994)
R&D Personnel	+	Absorptive capacity	Cohen & Levinthal (1989)

Expenditure		Spillover effects from R&D in developed countries to developing ones	Coe et al. (1995); Huang & Liu (1994)
ICT	+	Higher growing firms exploit the adoption integrated technologies more than lower growing firms	Brasini & Freo(2012)
		Investment in ICT is not the only way of achieving higher economic growth. ICT generates complementary effects on the variables as human capital and structural change in the different sectors	Castiglione (2012)
		Higher economic growth depends on technological progress	Dimelis & Papaioannou.(2010)
	n.s.	Lack of significant effect of the internet use for sales in firm's efficiency	Romero & Rodriguez(2010)
Software Investment	+	Software investment increases the scale of firm operations	Becchetti et al. (2003)
Subcontracting Expenditure	+	Network effect	Aoki(1989);Lazonick(1990);Burki & Terrel(1998);Taymaz & Saatci(1997)
Subsidy	-	Renk seeking behaviour	Martin et al.(1983)
	n.s.	Subsidies go to R&D performers	González et al. (2005)
Time effect	+	Privatization of the state monopoly	Jha & Majumdar (1999);Ross et al. (1996);Bortolotti et al (2002), Lam & Shiu (2010)

TABLE 2. Empirical Studies on the Effect of ICT on Efficiency

Authors	**Title of the paper**	**Targeted population**	**Result**	**ICT component**
Castiglione(2012)	Technical efficiency and ICT investment in Italian manufacturing firms	3452 Italian manufacturing firms over the period 1995 to 2003	• Positive and significant effect of ICT investment on technical efficiency. • Group, size, and geographical position have positive influence on technical efficiency. • Older firms are more efficient than younger firms	ICT investment takes the value of 1 if firm makes ICT investment
Becchetti et al. (2003)	ICT investment, productivity, and efficiency evidence at firm level using a stochastic frontier approach	4400 Italian SME's over the period 1995 to 1997	• Software investment increases the scale of firm operations • Telecommunication investment creates flexible production network which products and processes are more fequently adapted to satisfy consumers' taste for variety	This indicator is used as a decomposed form; hardware, software, and telecommunication investment
Romero & Rodriguez(2010)	E-commerce and efficiency at the firm level	Spanish manufacturing firms over the 2000 to 2005	• Positive influence of e-buying on efficiency while e-selling has no effect	Binary variable if firms makes e-buying or e-selling
Shao & Lin(2001)	Measuring the value of information technology in technical efficiency with stochastic frontier productions	US firms over the the period 1988 to1992	• Positive effect of IT on efficiency	Hardware investment and information systems staff expenditure
Dimelis & Papanniou (2010)	The role of ICT in reducing inefficiencies. A Stochastic Production Frontier Study across OECD countries	17 OECD countries countries over the period 1990 to 2005	• A significant ICT impact in the reduction of cross country inefficiencies. • European countries are less efficiency and have not yet converged to the efficiency levels of the most developed OECD countries.	ICT investment as a share of GDP
Mouelhi(2009)	Impact of adoption of information and communication technologies on firm efficiency in the Tunisian manufacturing firms	Tunisian manufacturing firms	• Positive effect of ICT capital on efficiency is observed after controlling for human capital related firm characteristics	ICT index composed of communication ratio, hardware acquisitions ratio, and software acquisitions ratio
De Vries & Koetter (2011)	ICT adoption and heterogeneity in production technologies: Evidence for Chilean Retailers	Chilean Retail Firms	• Positive effect of ICT on determining production technologies	ICT index varying from 0 to 7. Index is generated by using internet, intranet, extranet, and webpage onership

TABLE 3. Stochastic Production Frontier Estimation Results for High Technology Firms

A. Frontier Functions	*Coefficients*	*t-statistics*
Constant	0.10	5.19
K	0.14	17.09
L	0.02	2.13
RM	0.59	72.43
E	0.05	5.86
T	0.04	5.98
*K*K*	0.02	5.73
*K*L*	-0.01	-2.07
*K*RM*	-0.08	-11.89
*K*E*	0.04	6.14
*K*T*	-0.01	-2.29
*L*L*	0.00	0.47
*L*RM*	0.01	1.46
*L*E*	0.00	-0.49
*L*T*	0.00	-0.56
*RM*RM*	0.09	27.70
*RM*E*	-0.05	-8.29
*RM*T*	0.03	6.14
*E*E*	0.01	3.01
*E*T*	-0.01	-2.00
*T*T*	0.03	5.80
Chemicals	0.19	7.37
Electricity	0.05	2.27
Machinery	0.03	1.29
B. Inefficiency Effects Model		
Constant	-0.88	-1.98
Trade Openness	-1.11	-5.84
Outsourcing	-3.66	-7.37
Regional Agglomeration	-2.13	-7.30
R&D personnel	-0.44	-4.40
Software investment	-0.12	-5.60
Year 2004	-1.15	-7.85
Year 2005	-1.54	-8.08
Year 2006	-2.31	-12.71
Year 2007	-0.83	-7.36
Variance Parameters,loglikelihood, and mean efficiency		
$\sigma^2 = \sigma_2^u + \sigma_2^v$	0.75	9.34
$\gamma = \sigma_2^u / (\sigma_2^u + \sigma_2^v)$	0.94	116.99
Loglikelihood	-357.52	
Mean efficiency	0.83	
Number of observations	2212	

Transportation is the base sector

TABLE 4. Stochastic Production Frontier Estimation Results for Low Technology Firms

A. Frontier Functions	***Coefficients***	***t-statistics***
Constant	-0.01	-0.30
K	0.08	13.80
L	-0.01	-1.67
RM	0.66	98.28
E	0.03	4.51
T	0.03	4.84
*K*K*	0.01	5.20
*K*L*	0.01	1.62
*K*RM*	-0.04	-8.21
*K*E*	0.00	0.65
*K*T*	0.00	-0.20
*L*L*	0.00	1.21
*L*RM*	0.00	0.71
*L*E*	0.00	0.60
*L*T*	0.00	0.35
*RM*RM*	0.10	35.80
*RM*E*	-0.04	-6.97
*RM*T*	0.02	4.68
*E*E*	0.02	4.88
*E*T*	-0.01	-2.80
*T*T*	0.03	5.08
Food	-0.01	-0.37
Textiles	0.14	4.65
Paper	0.17	5.32
Unclassified manufacturing	0.02	0.62
B. Inefficiency Effects Model		
Constant	0.39	2.62
Export share	-5.63	-13.13
Outsourcing expenditure	-0.21	-3.38
Outsourcing income	0.00	0.00
Subsidy	0.03	0.75
Regional Agglomeration	-0.07	-1.00
R&D personnel expenditure	-0.23	-5.75
Software investment	-0.08	-4.00
Subcontracting expenditure	-0.52	-5.77
Year 2004	-0.21	-3.50
Year 2005	-0.36	-4.50
Year 2006	-0.97	-6.06
Year 2007	-0.23	-3.29
Variance Parameters,loglikelihood, and mean efficiency		
$\sigma^2 = \sigma_2^u + \sigma_2^v$	0.28	7.00
$\gamma = \sigma_2^u / (\sigma_2^u + \sigma_2^v)$	0.78	19.50
Loglikelihood	-1111.6	
Mean efficiency	0.82	

Number of observations	4160

TABLE 5. Test results

Null hypothesis	*Loglikelihood Value*	*Test Statistic*	*Decision*
Cobb Douglas production All β's are equal to zero			
High Technology Sectors	-691,03	666,06	Ho Reject
Low Technology Sectors	-1738,4	1253.6	Ho Reject
No Inefficiency $H_0 : \gamma = \delta_0 = ...\delta_{n=0}$			
High Technology Sectors	-632	548	Ho Reject
Low Technology Sectors	- 1456	688.8	Ho Reject
Non Stochastic Inefficiency $H_0 : \gamma = 0$			
High Technology Sectors	-632	533,2	Ho Reject
Low Technology Sectors	-1456	314	Ho Reject
No Inefficiency Effects $H_0 : \delta_1 = ...\delta_n = 0$			
High Technology Sectors	-365,4	14,8	Ho Reject
Low Technology Sectors	-1299	375	Ho Reject
Time Invariant Inefficiency $H_0 : \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$			
High Technology Sectors	-363.8	32.4	Ho Reject
Low Technology Sectors	-1154.01	86	Ho Reject

TABLE 6. Variable Definitions

Output (Q)	Output which is measured as manufacturing sales-changes in finished good inventories
Capital Stock (K)	Depreciation Allowances
Labor (L)	Average Number of Employees
Raw Material (RM)	Total value of intermediate goods
Electricity and Fuel (E)	Electricity and fuel purchased
Time (T)	Time (t,1,...5)
Industry Dummies	Food (Nace 15-16),textile (Nace 17-18), leather (Nace19),wood (Nace20),paper (Nace21-22),chemicals (Nace25),plastics (Nace25),nonmetals (Nace 26), metals(Nace 27-28),machinery(29), electricity(Nace30-33),transportation equipment(Nace 34-35), and unclassified manufacturing(Nace 36-37)
R&D Personnel	Dummy variable which takes the value of 1 if the firm invests in R&D personnel expenditure
Regional Agglomeration	Share of the firm's revenues to the total revenue of the region
Software Investment	Share of software investment to total intangible investment
Trade Openess	Share of total product and services exports to total revenues
Outsourcing revenue	The share of total outsourcing expenditure to total expenditure
Outsourcing expenditure	The share of total outsourcing revenues to total revenues
Subsidy	Dummy variable which takes the value of 1 if the firm receives subsidy and 0 otherwise
Suncontracting	The share of subcontracting expenditure to total expenditure
Time Effects	Dummies for each year from 2004 to 2007. 2003 is a reference year(d_2004, d_2005, d_2006, d_2007)

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KEY TERMS AND DEFINITIONS

Intangible investment: This term indicates all products or services that cannot be measured directly (e.g. knowledge, R&D, software,... etc.).

R&D: Research and development activities**.**

Software-intensive firms: Firms that invest heavily in software products or services.

Stochastic frontier analysis: A parametrical method of measuring technical efficiency.

Tangible capital: This term includes all types of physical capital such as buildings and machinery.

Technical efficiency: It is measured as a distance of a firm from efficient production frontier.

Translog production function: A flexible functional form that does not impose any prior restrictions on production function.

ENDNOTES

[i] The share of high technology firms receiving government subsidy and being involved in subcontracting relations is quite low. Those variables are not included in the efficiency estimation of high technology firms.

[ii] [ii]Changes in productivity occurs due to the differences in production technology, differences in the efficiency of production process, and differences in the production environment(Kumbhakar & Lovell,2000). Hence, efficiency is only one of the components meaning that productivity can increase or decrease even there is no change in the efficiency.

[iii] R&D activities are used as a proxy for innovation.

[iv] Tacit knowledge cannot be transmitted through communication in a direct way, rather it is built up by direct experience Polanyi &Sen (1967). In a trust relation, firms learn from each other without awareness. Therefore, it refers to the process of assimilating ourselves things from outside.

[v] We constructed balanced panel dataset in order to trace the firms making software investment each year between 2003-2007.

[vi] The classification based on the R&D intensity has some deficits. To illustrate, high technology firms can produce goods in the range from low technology to high technology. The idea behind creating such an index was to determine a common trajectory for OECD countries (OECD, 2011).