ICT ADOPTION, SOFTWARE INVESTMENT AND FIRM EFFICIENCY IN TURKEY

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ABSTRACT

ICT ADOPTION, SOFTWARE INVESTMENT AND FIRM EFFICIENCY
IN TURKEY

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This thesis examines the impact of firm resources on Information and Communication Technologies (ICT) adoption by the Turkish business enterprises and the impact of software investment on firm efficiency by using firm level data. ICT adoption is measured at three levels: The first level is technology ownership. The second level is the presence of enterprise resource planning (ERP) and customer resource management (CRM). The third level is the use of narrowband and broadband technologies. The impact of firm resources on each technology level is tested by exploiting cross section and time dimension of the panel data. In the cross sectional analysis, two year time lag between ICT adoption variables and firm resources is introduced. In the panel data analysis, the time lag is extended to four years to test whether the firm resources generate similar effects as the time lag is extended. Therefore, we could mention two main effects of the firm resources on ICT adoption. These are immediate effects and long term effects. Immediate effects could arise when the time lag between firm resources and ICT adoption is two years. Long term effect indicates four year time lag between firm resources and adoption. According to the results, some firm resources generate only immediate effects while others have both immediate and long term effects on ICT adoption.

This thesis also analyzes the effect of intangible investment on firm efficiency with emphasis on software component of ICT. Stochastic 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. During this period, the number of firms making software investment decreased while those firms which already made software investment in the past became more software-intensive. The main question asked is as follows. Is the increase in the intensity of software investment turns into efficiency gains for the Turkish manufacturing firms? Firms are classified based on their technology type. 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, which is another intangible investment.

Keywords:ICT adoption, firm resources, software investment, firm efficiency

ÖZ

TÜRKİYE'DE BİLGİ VE İLETİŞİM
TEKNOLOJİLERİNİN (BİT) ADAPTASYONU YAZILIM
YATIRIMLARI, VE FİRMA ETKİNLİĞİ ANALİZİ

FINDIK, Derya
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Bu tez, Türkiye'de firma kaynaklarının bilgi ve iletişim teknolojilerinin (BİT) kullanımı üzerindeki etkileri ve yazılım yatırımının firma etkinliği üzerindeki etkisini incelemektedir. BİT kullanımı 3 farklı düzeyde ölçülmüştür. İlki teknoloji sahipliği modelidir. İkincisi, kurumsal kaynak planlaması (ERP) ve müsteri kaynak yönetimi (CRM) sistemlerinin kullanılmasıdır. Üçüncüsü ise genişbant ve darbant teknolojilerinin kullanılmasıdır. Firma kaynaklarının sayılan her bir teknoloji düzeyinde etkisi gerek kesit gerekse panel veri analizi kullanılarak incelenmiştir. Yatay kesit analizinde, firma kaynaklarının teknolojiyi kullanma kararı üzerinde iki yıl gecikmeli etkisi olduğu varsayılmıştır. Panel veri analizinde ise, firma kaynakları ile teknoloji değişkeni arasındaki zaman aralığı dört yıla çıkarılmıştır. Böylece, firma kaynaklarının teknolojiyi kullanma kararı üzerinde erken ya da gecikmeli etkilerinin olup olmadığı test edilmiştir.

Tahmin sonuçlarına göre, bazı firma kaynaklarının teknoloji üzerinde yalnızca erken etkileri olduğu gözlemlenirken, diğer firmalarda hem erken hem de gecikmeli etkiler bulunmuştur.

Bu tez aynı zamanda, maddi olmayan yatırımlardan biri olan yazılım yatırımlarının firma etkinliği üzerindeki etkisini incelemektedir. Etkinlik analizi, üretim fonksiyonu ve teknik etkinliğin belirleyicilerinin eşzamanlı olarak tahmin edildiği stokastik sınır yöntemi kullanılarak gerçekleştirilmiştir. Çalışmanın bu bölümünde Türkiye'de 2003-2007 yılları arasında yazılım yatırımı yapan imalat sanayi firmaları yer almaktadır. O yıllarda, yazılım yatırımı yapan firma sayısı azalırken, halihazırda yazılım yatırımı yapan firmaların bu yatırımlarında artış gözlemlenmektedir. Tezin bu bölümünde yazılım yatırımı yoğunluğunun etkinlik düzeyinde olumlu bir etki sağlayıp sağlamadığı incelenmiştir. Bu incelemede yüksek teknolojili firmalar ve düşük teknoloji firmalar olmak üzere iki farklı firma grubuna odaklanılmaktadır. Çalışmanın sonuçlarına göre, yazılım yatırımlarının firma etkinliği üzerinde olumlu etkisi vardır. Bu etki yüksek teknolojili firmalarda daha yüksektir. Bununla birlikte, yüksek teknolojili firmalar grubunda, AR-GE personeli harcamalarının yazılım yatırımlarına göre etkinlik üzerinde daha belirleyici bir role sahip olduğu ortaya çıkmıştır.

Anahtar sözcükler: BİT kullanımı, firma kaynakları, yazılım yatırımı, firma etkinliği

To my Mom and Dad

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LIST OF ABBREVIATIONS

ICT	Information and Communication Technology
LAN	Local Area Connection
WLAN	Wireless Local Area Connection
ERP	Enterprise Resource Planning
CRM	Customer Resource Planning
EU	European Union
R&D	Research and development
TURKSTAT	Turkish Statistical Institute
ISDN	Integrated Services Digital Network Connection
ADSL	Asymmetric Digital Subscriber Line
FWA	Fixed Wireless Internet Connection
Wi-Fi	Wireless Fidelity
DEA	Data Envelopment Analysis
TUBITAK	Scientific and Technical Research Council of Turkey
SPO	State Planning Organization
GDP	Gross Domestic Product
DPT	Devlet Planlama Teşkilatı
TUENA	Turkish National Informatics Infrastructure Master Plan
S&T	Science and Technology
SWOT	Strengths, Weaknesses, Opportunities, Threats
MEMs	Microelectromechanical Systems
ERA	European Research Area
SME	Small and Medium Sized Enterprises
M-form	Multidivisional Organizational Structure
1G	First Generation Mobile Technology

2G	Second Generation Mobile Technology
3G	Third Generation Mobile Technology
B2B	Business to business
B2C	Business to customer
SBTC	Skill biased technological change
SBOC	Skill biased organizational change
OLS	Ordinary Least Square
GLLAMM	Generalized Linear, Latent, and Mixed Models
BUC	Blow up and Cluster
ML	Maximum Likelihood
ABPRS	Address Based Population Registration System
NUTS	Nomenclature of Territorial Units for Statistics
GPRS	General Packet Radio Service
IPRs	Intellectual Property Rights
SFA	Stochastic Frontier Analysis
KOSGEB	Küçük ve Orta Ölçekli İşletmeleri Geliştirme ve Destekleme İdaresi Başkanlığı

CHAPTER 1

INTRODUCTION

Information and communication technology (ICT) adoption and the returns from it are at the center of the development literature. Most of the developing countries such as Turkey have not yet shifted from being technology user to being technology producer despite the increasing number of internet users in these countries. Thus, it is necessary to determine the level of technology usage before formulating a policy on technology production. To this end, this thesis mainly aims to investigate the extent to which advanced technology is used in Turkey by using both cross section and panel data analysis. In the cross section analysis, a two-year time lag between adoption variables and the firm specific factors is introduced. In the panel data analysis, the time lag is extended to four years. Therefore, the study focuses on whether the firm specific factors generate similar effects in the short term and the long term. The thesis also aims to explore the effect of software investment on firm efficiency. During the period of 2003-2007, the number of firms making software investment decreased in Turkey. On the other hand, the firms which had already invested in software became more software-intensive. The thesis, thus, aims to reveal whether the increase in the intensity of software investment resulted in efficiency gains for the Turkish manufacturing firms.

There are three main factors related to the ICT adoption: pace of adoption, rate of adoption, and the network effect. The adoption pace pertains to the speed with which the technology is adopted. The rate of adoption relates to the relative speed in which members of a social system adopt an innovation.

Network effect is concerned with the increase in the utility of the adopter with the diffusion of the technology.

The first factor, adoption pace, indicates how fast the technology is adopted. In fact, it heavily depends on the technology itself. The adoption of some technologies occurs right after they are introduced. Adoption becomes faster if the introduction of one technology depends on another. The opposite is the case if the technology is completely new to the subjects. Rosenberg (1972) points out the role of other factors such as economic forces which affect the speed at which adoption occurs. For instance, heavy taxes on high technology products slow down the adoption by impeding the investment on these technologies.

The second factor related to the ICT adoption is the rate of adoption. It indicates the relative speed at which members of a social system adopt an innovation. According to Hall and Khan (2003), the rate of adoption is strongly linked to the benefits and costs of adoption. How the technology is transformed into benefits is determined largely by the firm specific factors and the environmental factors. For instance, the availability of skilled workers in a firm accelerates the diffusion and generates a spillover effect on the potential adopters in the firm, which increases the rate of adoption at the end of the day. Similarly, if the technology requires new skills that are difficult to learn, the adoption process slows down. In addition, environmental factors such as the technical capacity of the industry, in which the firm operates, also affect the adoption rate (Rosenberg, 1972). If skilled workforce exists or the horizontal relations are well developed in that industry, the new technology will spread among workers rapidly.

Furthermore, an improvement in a new technology is a supply side factor determining the adoption rate. The idea behind such improvements is that the efficiency gain is much larger at the stage following the implementation of the technology. Therefore, time lag is needed for diffusion. In Turkey, with the widespread use of computers in the firm operations, the use of technologies such as wireless local area network (WLAN) and enterprise resource planning (ERP) increased. The share of WLAN using firms in Turkey increased by 10 percent from 2007 to 2009. During the same period, the share of ERP users increased by 20 percent (TURKSTAT, 2007-2009).

The third significant factor for the ICT adoption is the network effect. Direct network effect is produced when the utility of the adopter increases with the adoption of the technology. Indirect network effect arises when two technologies are complementary that the increase in utility generated by one technology depends on the other. Creation of value in e-business depends on the existence of the complementary technologies in the firm (Amitt and Zott, 2001). The network effect of ICT adoption is investigated in the first part of this study by analyzing the technology ownership which is an index composed of LAN, WLAN, intranet, and extranet technologies. Those technologies have complementary functions. For instance, the intranet technology coordinate the transactions within the firm while the extranet technology connect the firm with the external market. It is hypothesized that the firms using all these technologies gain advantage compared to the firms having only one of these technologies.

This thesis comprises two main parts. The first part analyzes the effect of firm specific factors on ICT adoption of the firms in Turkey. The second part investigates the effect of software investment on firm efficiency. In the first part of the study, ICT adoption is evaluated at two levels. At the first level, adoption is treated as a decision at one point in time; therefore, a cross sectional analysis of the firm level is conducted. The ICT adoption process firms go through is analysed. Various firm specific factors are considered to be the main factors determining the adoption decision of the firm. The dependent variables for adoption come from the 2009 wave of "ICT Usage

Survey" (TURKSTAT 2009). The explanatory variables (firm specific factors) belong to 2007 wave of "Annual Structural Business Statistics Survey"(TURKSTAT 2007a). A two year-lag between ICT adoption and its determinants is introduced based on the hypothesis that firm specific factors have lagged effects on ICT adoption.

At the second level, adoption indicates a diffusion process. Hence, panel data analysis is used to test two main hypotheses. The first hypothesis is related to the "panel effect". A considerable time lag is needed both for the introduction of a new idea and its diffusion (Rogers and Shoemaker, 1971). Accordingly, adoption process consists of multiple stages: awareness, interest, evaluation, and trial. In the awareness stage, the firm or the individual learns the existence of the technology, and in the following stage, it develops an interest in that technology. In the evaluation stage, the individual or the firm evaluates the costs and benefits of adopting this technology for present and future. At the trial stage, the new technology is used on a small scale to determine its utility or its return. Therefore, the firm may not adopt the technology immediately, and it may delay the adoption until sometime later. The second hypothesis is related to the lagged effects of the firm specific variables on adoption. The cross section analysis presents a two-year lag between ICT adoption and the factors that determine the ICT adoption. The panel data framework uses a four-year lag to test whether the firm specific factors generate similar effects on the ICT adoption when the time lag is extended.

The second part of the thesis analyzes the effect of software component of intangible investment on firm efficiency of the manufacturing firms in Turkey. In recent years, the share of intangible investment in the manufacturing sector has increased while the share of tangible investment has decreased for the EU countries such as Germany, Netherlands, Belgium, Italy, and Spain. Intangible assets can be classified in several ways. Corrado et al. (2009) developed the latest one. According to their classification, intangible assets include computerized information, scientific and creative property, and economic competencies. Software is an example of computerized information. Research and development (R&D) activities, copyrights and license costs are components of scientific and creative property. Brand equity and firm specific human capital are the economic competencies. In Turkey, there has been an increase in the software intensity in between 2003-2007. This part of the thesis aims to examine the effect of the software intensity on firm efficiency.

The thesis is organized as follows. Following the introduction, Chapter 2 presents the history of ICT usage in Turkey and discusses the early efforts on data collection on ICT usage and the policies developed in order to build up ICT infrastructure. Chapter 3 dwells on the investigation of the determinants of ICT adoption by the firms. Chapter 4 is devoted to the investigation of the effect of software investment on firm efficiency. Finally, the last chapter presents the overall findings and provides a set of policy implications.

Chapter 2 focuses on the policy documents and surveys on ICT usage in Turkey. According to the results of the first survey in 1971, the computer usage was highest in the services sector such as in the financial, insurance and business services. In these sectors, computers were mostly used for sales of expendables.

In the following years (1980-1982), the number of firms that provide informatics related services increased by 50 percent. Since the public sector was the main consumer of informatics related services, there was no specific marketing strategy for these services (TURKSTAT, 1983). The Household Survey on ICT usage was conducted in 1997. It revealed that there was a positive relation between income and computer ownership. The majority of the PC owners was from the high income group. The same survey showed that telephones were only used for calling and texting. In low income groups, the number of telephone users was higher than the number of the computer users. The Households ICT Usage Survey (2005) found that the gap in the distribution of the ownership of the desktop and laptop computers among urban and rural households was massive. As for the ownership of mobile phones, in contrast, the gap between those groups was minor.

Chapter 3 elaborates the firm specific determinants of ICT adoption by presenting theory and empirical literature. There are two theoretical views in the adoption literature: Classical adoption theories and contemporary adoption ones. Classical adoption theories are based on the S shape curve of adoption rate over time. It has a logistic distribution and shows the relation between cumulative adoption rate and time. The initial stage of the growth is exponential on the curve. When it reaches a saturation point, the growth slows until it stops at the maturity point. Adoption theories use influence models to explain the determinants of the shape of the curve. These are named as internal influence and external influence models. Internal influence models assume that diffusion occurs through interpersonal communication. This necessitates the interaction between the prior adopters and the potential adopters. This model underestimates the role of other factors in the adoption. External influence models assume that diffusion occurs depending on the factors that are external to the social system. In contrast to the internal diffusion model, the interaction between prior adopters and potential adopters is not allowed in the external diffusion model.

A more recent model is called the multi stage diffusion model. It assumes that the diffusion is shaped by the characteristics of the technology. These characteristics are independency, complementarity, contingency, and substitutability among various technological forms. Independency implies that innovations are independent from each other since they have different functions. On the other hand, the adoption of one innovation enhances the adoption of the other. Therefore, the different functions could be complementary to each other. In addition, the adoption of one technology could be conditional on the presence of the other. Those technologies are named as contingent technologies. Both internal and external factors play a role in the adoption of the contingent technologies. In some cases, one prevails over the other. To illustrate, internet technologies grew mostly based on the presence of internal competencies such as organizational infrastructure. Substitutability is another feature that could be established between old and new technologies. The adoption of one technology could generate a decrease in the demand for other technologies.

Contemporary adoption theory is rather concerned with the presence of strategic firm specific factors in the adoption of the technology. Three types of models are introduced in the literature: rank, epidemic, and stock and order models. Rank models are based on ranking adopters in terms of their returns from adoption. User characteristics come to the fore in this model. For instance, the size of the firm plays a determining role in the early adoption of the technology since large firms have greater access to knowledge of the recent technology. The epidemic model involves learning from the others. The common indicators of the epidemic model are environmental factors such as region and industry. If the firms are agglomerated in some regions or industries, frequency of contacts among firms could increase. Hence, potential adopters may become aware of the new sources and decide to adopt the technology learning from the existing users. The stock and order models are based on the game theoretic approach. These models assume that, as the number of previous adopters increases, the potential adopters gain less. In other words, the profitability of adopting a new technology is negatively associated with the previous returns. This model is not applied in this thesis due to the lack of data on profits from adoption.

ICT adoption is measured by the following indicators in this thesis: technology ownership, the use of enterprise resource planning (ERP) and customer resource management (CRM), and the use of narrowband and broadband technologies. An item in the survey questions the type of the technology a particular firm owns to estimate its technology ownership. Four alternatives for the types of technology are given in the survey. The first is the Local Area Network (LAN), which is used for data exchange among fixed points in a limited area. The second one is the Wireless Local Area Network (WLAN), which is wider and which enables the user mobility. This technology has been used increasingly with the introduction of the laptop computers. The third one is the Intranet, which is used for intra-firm knowledge sharing. This system works on the basis of confidentiality, i.e. only authorized subjects are able to connect with each other. The last one is the extranet, which is the secure extension of the intranet. It enables the users to communicate with their strategic partners and customers. In the first part of the study, technology ownership index is created by using the ownership of these items indicated in the survey. In this thesis, it is hypothesized that a firm specific variables play a major role in the adoption of technology in particular while advancing from single technology to the complementary ones.

In addition to technology ownership, the use of specific technologies such as ERP and CRM is also investigated. ERP is a system which integrates different functions of the firm into a single computer system (Nelson and Somers, 2001). Therefore, with the contribution of ERP system, the resources a firm has could be managed by using both internal and external information. Due to its high installation costs, large firms invest in the ERP system.

CRM system is used to manage the relationship between the customers and the suppliers. The intensity of these relations is affected by the firm environment such as the industry that the firm operates in. Both regions and the industry variables are considered in this thesis in order to control their effects on the usage of CRM. In this thesis, it is hypothesized that the firm specific factors generate differential effects between the use of ERP and CRM technologies.

The thesis also intends to shed light upon connection types. In the survey, enterprises were asked the types of external connection they had to the Internet. The types of external connections are traditional modem or Integrated Services Digital Network connection (ISDN), Asymmetric Digital Subscriber Line (ADSL), other fixed internet connection, and mobile connection. The aim of this question is to investigate whether firms differ in terms of using old and new technologies. Traditional modem or ISDN is in the old technology group, which provides time-restricted connection through modem, and they are called as “narrowband” due to low connection speed. ADSL is a typical example of broadband connection and allows for higher speed data transmission than ISDN connection. Although ADSL is built on the ISDN system, it works differently. ADSL is widely used for various internet applications. It is asymmetric because downloading speed is faster than the uploading speed, which makes internet surfing easier and attractive for users. Other fixed internet connection facilities include Cable Modem Connection, High Capacity Leased Line, Fixed Wireless Internet Connection (FWA), and Wireless Fidelity (Wi-Fi). All these connection types are given as an example of other fixed connections in the question. No information is available on the usage of each item in the questionnaire. In this thesis, it is hypothesized that the use of old technologies does not require the same amount of firm specific factors as the use of new technologies.

Chapter 3 also dwells on the empirical evidence of the determinants of ICT adoption by the firms. Based on the rank and epidemic models, firm specific variables such as firm size, foreign share ownership, export share in sales, R&D personnel expenditure, purposes of ICT usage, and organizational environment function are used as the determining factors of technology adoption in this thesis. A positive association between firm size and technology adoption is expected since large firms have access to resources and own the infrastructure required for the adoption of the new technology. Cohen and Levin (1989), based on the Schumpeterian perspective, discussed the link between the firm size and innovative activity in terms of availability of internal funds and diversification. The assumption is that large firms are better able to innovate since they have the financial capabilities that are not available to the small firms. In addition, especially for information goods, product differentiation plays a crucial role in having competitive advantage, and large firms producing the “best” products gain cost advantage over small competitors (Shapiro and Varian, 1999, p. 25). Rothwell (1972) describes the causes of the best products’ success. These are meeting user needs, using effective marketing strategies, applying an appropriate management strategy for product development, utilizing external technology and facilitating knowledge exchange with academic community on a related innovation activity, and the existence of individuals playing a strategic role in both technical and business side to the product development. Therefore, firms achieve product differentiation through organizing all these steps into the production process.

The role of foreign share in ownership on ICT adoption is largely studied especially from an economic development perspective. In developing countries, the presence of foreign capital helps firms learn new skills. However, when the outsourced activities do not necessitate a technological expertise, foreign capital does not provide any advantage. If there are large differences in the costs of skilled labor between two countries, foreign firms choose to invest in the cheaper one. Furthermore, translating foreign capital investment into domestic skills closely depends on the existence of firm infrastructure. If the developing country invests in learning the transferred technology through reverse engineering, it attracts more technology from the multinationals. Moreover, political environment in the developing countries plays a crucial role in the investment decisions of the foreign firms. For example, tax reduction on foreign capital or relatively low labor costs are pull factors for multinationals.

Exporting activities are another factor that impact adoption of the ICT.The hypothesis is that exporting firms are better able to adopt new technologies through external linkages. Due the competitive pressure in the international market, firms could be forced to adopt the new technology. In addition, the content of the exporting activity may require the adoption of the technology.

As far as the effect of human capital on ICT adoption is concerned, technology diffusion studies focus more on the role of user acceptance in the time of adoption and the rate of adoption. Therefore, the adoption of the technology is assumed to be strongly related to the knowledge and the educational level of the users. High skilled workforce leads to earlier adoption which in turn generates a spillover effect on the potential adopters.

In the literature, purposes of ICT usage could be based on cost reduction, improvement in the quality, or improvement in the input(Hollenstein, 2004; Arvanitis and Hollenstein, 2001). In this thesis,, two indicators such as e-banking and e-training are used. According to Methodological Manual for Statistics on the Information Survey (2009), e-banking activities are composed of web-banking, the consultation of financial information, and the use of internet for automatic data interchange between enterprise and the financial organizations. E-training refers to employees' participation in online training activities. Conducting banking activities through internet could reduce the transaction costs of the firm.

Organizational environment is another factor which affects the technology adoption. In this thesis, industry and the regional location are used as environmental factors. In order to control the heterogeneity in this respect, region and industry dummies are included in order to explain the ICT adoption. Five industry dummies are generated by using the taxonomy of O'Mahony and Van Ark (2003). According to this, industries are classified in terms of ICT use and production. Other industries which do not fall into these categories are called as non-ICT manufacturing/services industries. Agriculture and construction sectors are grouped under the name of 'other'. Therefore, it is assumed that the behavior of technology adoption differs across the industries. In some industries where R&D is the source of the competition, innovations are implemented by licensing and imitating while in the other industries, firms tacitly collaborate to keep potential entrants out of the market. Therefore, there is a bunch of diverse resources, structures and adopted strategies across industries.

The geographical location of the firm is also used in order to investigate region specific variation across firms. With the guidance of TURKSTAT (2008a), 12 regions in Turkey are reduced to six groups due to the lack of observation of some regions such as East Anatolia. The hypothesis is that ICT capability varies across regions. In regions where the number of software companies is high, ICT usage has spillover advantages. Therefore, the higher the number of the skilled workers is in a region, the higher economic, social, and cultural returns are expected. For instance, peripheral regions such as East and South-East Anatolia in Turkey are perceived as unfavorable environments for small and new entrant firms due to the lack of resources, information channels, entrepreneurial and workforce skills. As a result, firms in the underdeveloped regions lag behind the firms operating in the well-developed ones.Two observations are remarkable with the number of ICT-related patents by regions in Turkey for the years between 1998 and 2009 (see Appendix 11). The first one is the increase in the number of ICT-related patents during that period. The second one is the recent increase in the share of patents in Istanbul. This result sets forth the uneven distribution of the patents in the country.

Chapter 4 is devoted to the investigation of the effect of software investment on firm efficiency. There are two indicators of intangible investment for firm efficiency in Turkey during the period 2003-2007. First, the number of firms that invest in software decreased during this period. Second, the intensity of software investment increased in those years. In other words, software intensive firms became even more software intensive. This thesis aims to explain whether the increase in the software investment intensity resulted in higher efficiency for the Turkish manufacturing firms.

Time variant stochastic frontier model is used to explain the determinants of firm efficiency. Stochastic frontier approach is preferred because the alternative approach, Data Envelopment Analysis (DEA), has a major drawback; it cannot differentiate between the technical inefficiency and statistical noise. Time varying technical efficiency assumes that technical efficiency varies over time. Although the time period considered is rather short, time variant model is preferred in this thesis.

Chapter 5 gives the main conclusions and the policy implications for both ICT adoption and the firm efficiency. As for the adoption part, we observe two main effects. These are short term effect and long term effect. The first one is based on cross section analysis of adoption with two-year time lag The second represents the panel effect based on four-year time lag between firm specific variables and ICT adoption. As far as the effect of software investment on firm efficiency is concerned, this chapter dwells on the main policy implications of this intangible investment.

CHAPTER 2

HISTORY OF ICT USAGE IN TURKEY

ICT, due to its intangible component referred to as information, is difficult to measure. There are two main approaches namely neoclassical approach and evolutionary approach on the definition of information. Information which has a final consumption and price is treated as a commodity by neoclassical approach. According to evolutionary approach, it is not possible to measure information per unit since information is conceived as a process. Efforts on collecting data and designing policies on ICT are started based on the neoclassical approach to information. In this section, we provide a general overview of ICT usage in Turkey in terms of data collection and policy framework.

2.1. Early Efforts on Data Collection

The very first effort on collecting data on computers, data processing, and informatics has started in 1971 with the coordination of Scientific and Technical Research Council of Turkey (TUBITAK). Based on the results of the study, the computer usage was not at the desired level but computers were used in various fields. Services sector covering banking, insurance, trade, and education was the major sector that computer usage was high while the computer usage in the manufacturing sector was very small. This indicates that the services sector is much experienced in computer usage compared to the manufacturing sector.

In the Third Five Year Development Plan (1973-1977), the focus was on the spread of electronic data processing machines throughout the country.

TUBITAK and State Planning Organization (SPO) were selected to coordinate the diffusion of the computer usage in both public and private organizations. In order to determine the installed computer capacity in Turkey, SPO conducted a survey in 1978 which provided only a limited data due to the differences in definitions of ICT assets.

In the following years, Turkish Statistical Institute with the cooperation of Middle East Technical University initiated a project in order to determine the strength of computerization in the country. The survey was named as "Survey on Informatics Services in Turkey, 1980-1982" which included 106 establishments in the field of informatics services marketing. The data were collected related to informatics service areas, economic activity, total gross revenues, and the number of employees. The informatics service fields were ranked as providing software, consultancy, training, service-bureau, maintenance and repair, computer room preparation services and professional (informatics) publications, required for the efficient use of data processing equipment by productive sectors in the country.

As seen in Figure 2.1, financial insurance and business services have the greatest share in providing informatics related services. Manufacturing sector with a relatively small share follows this. Results for the remaining sectors are not in line with services and manufacturing sectors.

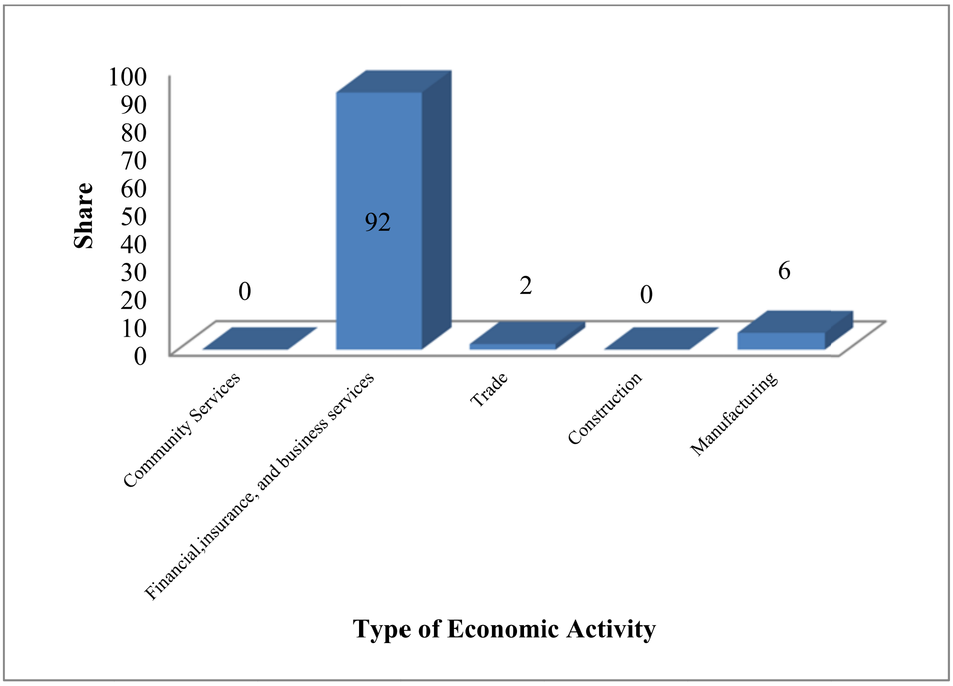

Figure 2.1. Ratio of Informatics Service Establishments' Gross Revenues to Total Revenues by Economic Activity in 1982 (%)
Note: The share of community services is 0.07. The share of construction is 0.04
Source: TURKSTAT (1983).

Figure 2.2 shows the distribution of the informatics services areas. According to these results, sales of expandable have the greatest share, while software development[1] assigns to the smallest share with 1 percent. The smallest share of the software development indicates that the underestimation of software development in production goes back to those years.

[1]Based on the definition by TURKSTAT(1983), software is defined as the total computer programs, operating procedures, rules and documentation related to proper functioning of a data processing system. This list includes operating system software, utilities, programming language translator and library as well as application programs. Examples are disk operating system software, computer network control software, a card-to-magnetic tape utility, a Fortran compiler, a program development support software, a general accounting application program package, an airlines reservation application software.

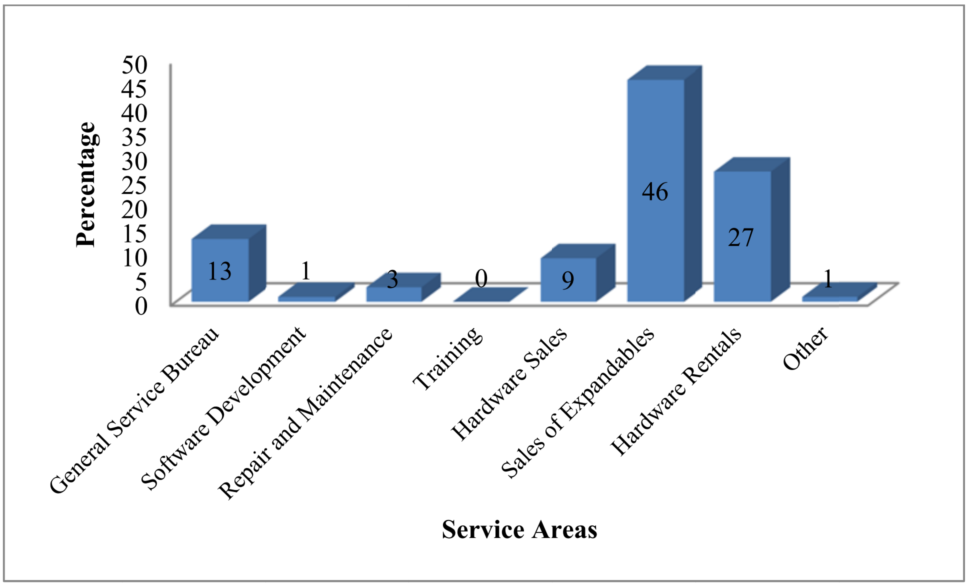

Figure 2.2. Informatics Service Establishments Gross Revenues by Service Areas (%)

Source: TURKSTAT(1983).

Looking at the distribution of the informatics related services, we see that almost for each sector, financial insurance and business services has a greatest share except trade. Training was a major informatics related activity for the trade sector in 1980-1982(see, Figure 2.3).

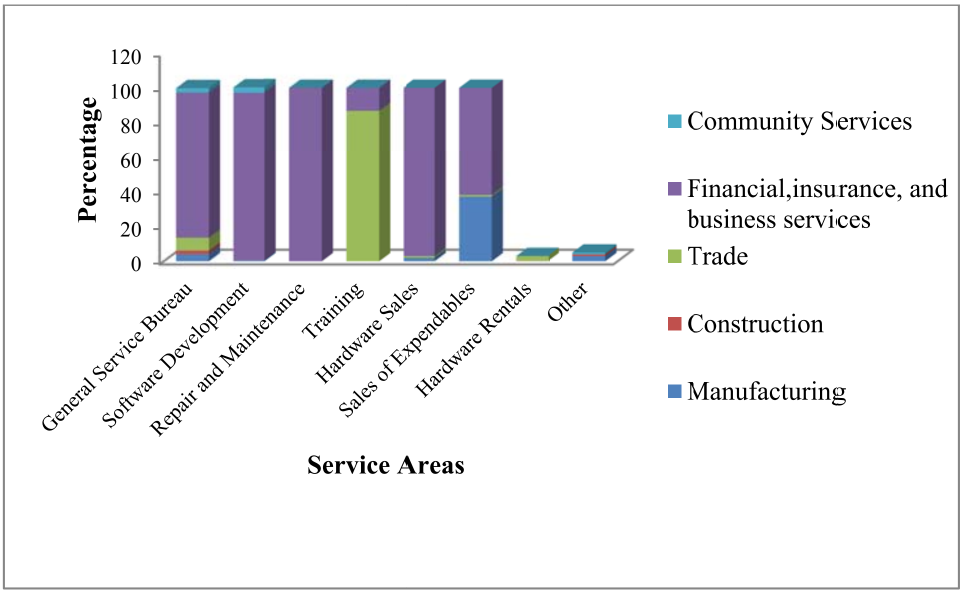

Figure 2.3. Distribution informatics related services by industry

Source: TURKSTAT(1983).

More extended version of the computer usage survey in Turkey was conducted in 1982. In that survey, detailed information on data processing centers was collected. These centers are marked by the economic activity, location, ownership, and year. Based on the data, from 1973 to 1982, the total number of data processing centers was about 345 in Turkey. 30 percent of the centers belonged to public sector and the 70 percent belonged to the private sector. In total, 41 percent of these centers operate in the manufacturing sector while 20 percent operate in the services sector. In terms of the geographical distribution, data processing centers were concentrated in Istanbul, Ankara, and Izmir.

After a long period of time since 1984, Turkish Statistical Institute (TURKSTAT) carried out ICT usage survey at household and enterprise level. Recent effort on collecting data on computer usage was in 2004 which targeted computer usage of households.

Main indicators in that survey were computer and internet usage, availability of devices such as PCs, portable computers, mobile phone, television, game console, handheld computer, fixed line telephone, digital camera, DVD, VCD, DivX player, printer, scanner, fax, multifunction device. In addition, the content of the internet usage was asked in the questionnaire. The list included sending or receiving e-mails as well as information search and online services.

Survey applications in the field of ICT have been restarted in 2005. The second wave was implemented by TURKSTAT two years later and the survey was conducted each year following the 2007 (see Table 2.3).

In order to check firms' readiness for e-business applications, barriers to e-commerce is analyzed to understand the extent of ICT readiness of firms by using the results of three waves of the ICT Usage Survey (see, Figure 2.4).

All variables are measured as a binary variable. Products and services incompatibility indicates that selling and marketing products online is not an appropriate strategy. Customers' reluctance towards online shopping reflects the approach of customers from a seller point of view because the questionnaire is only responded by the firms. Uncertainty related to the institutional framework shows to what extent regulations, laws, and legal framework for e-commerce activities are formulated based on the needs of the firms. The answers also rely on the firm point of view. Problems related to the online security reflect the lack of a system which eliminates the vulnerabilities that may arise during online transactions. The last one is the technical problems which occur due to the insufficient technical infrastructure. Immature legal and institutional framework in ICT policy, the insufficiency of existing regulations on data transactions, and the lack of IT personnel are mentioned as the main weaknesses (TEPAV, 2007).

Therefore, three waves of the survey from year 2007 to 2009 were merged. The last version of the survey includes 1241 firms. In the questionnaire, each question is asked at four level ranged from important to very unimportant. For the sake of simplicity, the scale was reduced into two categories as important and not important. If the response is important then then it takes the value 1 and it takes 0 otherwise[2].

The highest scores belong to the first category "products or services incompatibility" which shows that organizations are not ready to sell their products online. On the other hand, technical problems are not perceived as a serious barrier as observed in the rest of the variables. Moreover, in 2009 wave of the survey, all variables in the figure tend to decline which indicates an improvement in perceptions of firms towards e-commerce.

[2] The statement is negative but assigned value is 1.

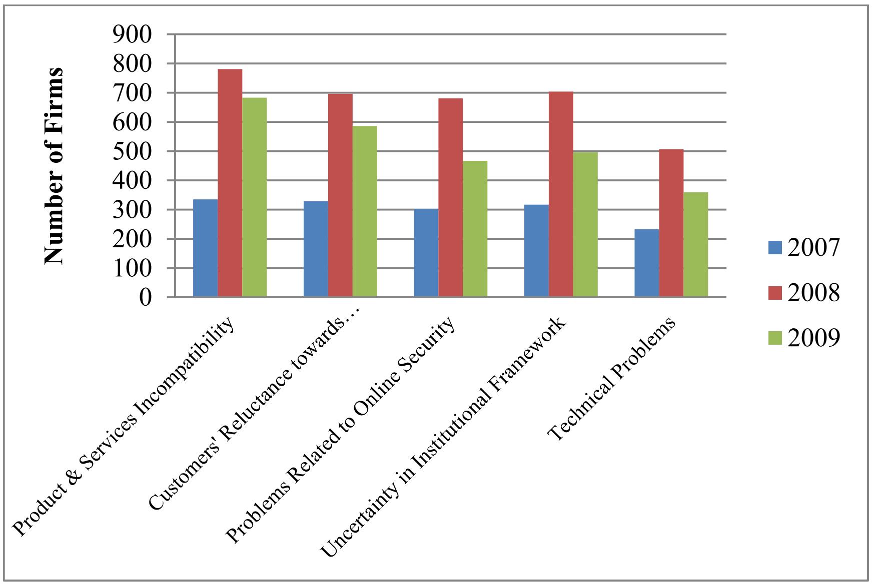

Figure 2.4. Barriers to E-Commerce (number of firms)
Source: TURKSTAT(2007-2009).

The term of "information society" was mentioned in the policy documents before 2007. However, the emphasis on its link with economic growth, equal distribution of income, competitiveness in the global market, and EU membership was first stated in the vision statement of 9th Development Plan (2007-2013). According to this, the widespread usage of ICT is emphasized as the main driver of gaining competitive advantage in the 9th Development Plan. On the other hand, there has not been done any firm level analysis including different regions and industries despite the emphasis of ICT's role in economic efficiency in those documents. This study analyzes the technology adoption at firm level across regions and industries. On the other hand, recentness of micro level data on ICT usage does not allow analyzing the term technology diffusion which requires the time span. To eliminate the static nature of the cross sectional analysis, two strategies are followed in this thesis. For the first strategy, independent variables are selected with two-year lags. Survey period includes the years between 2007-2009. Furthermore, ICT Usage Survey has been revised since the year that it was first implemented. It makes complicated to make a projection of three surveys. The second strategy is to introduce a short panel in this thesis. Accordingly, four-year time lag is introduced between dependent and independent variables. Dependent variables come from the dataset including the years between 2007 and 2011.Independent variables belong to the 2003-2007 Annual Structural Business Statistics Survey.

Another point related to ICT Usage Surveys in Turkey, the firm level data is not available before 2007[3]. Therefore, it is not possible to measure the effect of privatization which is an essential policy change for the sector. If there were information belong to the pre-privatization years then treating privatization as a structural break and making comparison between before and after privatization would be possible.

In addition, in policy documents, the proposition of increasing the information and technology usage rather indicates making improvements in IT sector. This goal underemphasizes the importance of e-commerce activities in other sectors.

At last, ICT usage statistics in these policy documents are limited by physical infrastructure such as fixed lines and internet connection. The existence of physical infrastructure represents the first stage of which the technology is introduced to the subjects. High fixed costs of investment on infrastructure in Turkey remain as challenge to move up adoption stage. ICT Usage Surveys reflect the current perception of the country. For instance, adoption indicators are measured on a binary scale. Moreover, there is no question on managerial ability, educational level of workers and managers, and centralization or decentralization of the firm, which creates incomplete understanding of adoption process.

[3] In fact, the Use of ICT by Enterprises Survey was first conducted in 2005. However, survey results are not published by TURKSTAT since most of the information is missing.

Looking at the trend in the diffusion of broadband internet, Turkey's broadband internet access increased between 2007 and 2010 except a sharp decline in this ratio from 2008 to 2009. The most remarkable point is that the broadband internet access of the country is higher than most European countries. In addition, the diffusion of the broadband internet tends to increase since 2007 (see Figure 2.5).

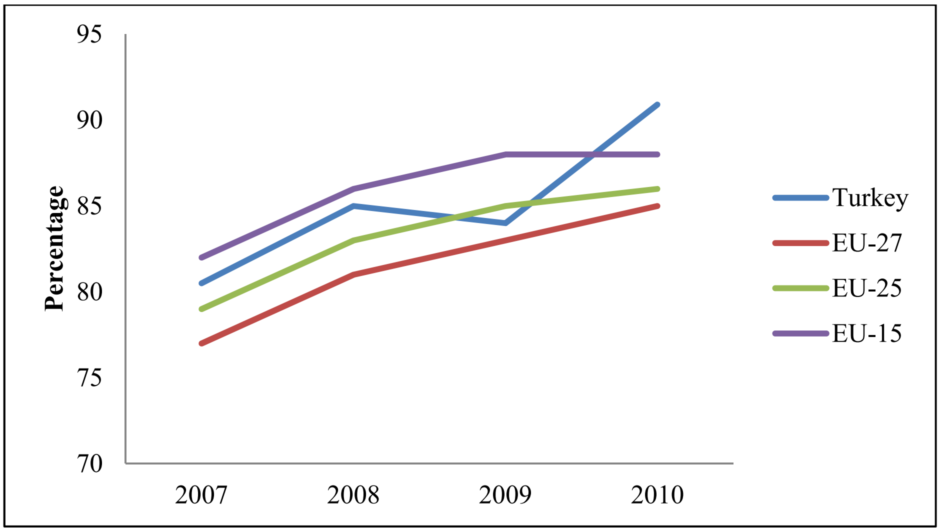

Figure 2.5. Ratio of Enterprises with Broadband Internet Access in Turkey and EU

Source: DPT(2011).

While the broadband access of Turkey is higher than most of the EU countries, the ratio of enterprises with internet access is lower in Turkey compared to the EU countries (see, Figure 2.6). This implies that the internet access is not at the desired level in Turkey. On the other hand, the use of other components of internet such as narrowband technology is lower than the broadband usage.

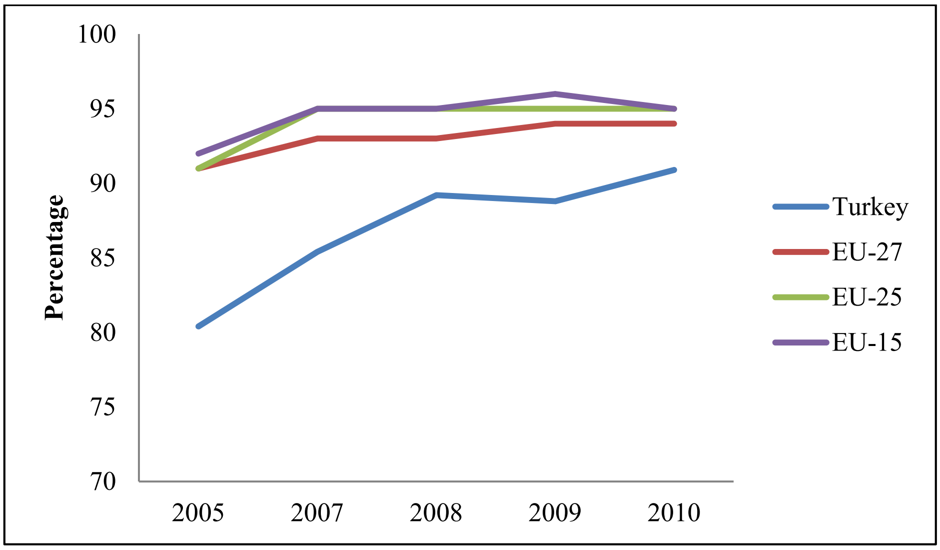

Figure 2.6. Ratio of Enterprises with Internet Access in Turkey and EU
Source: DPT(2011).

Besides the efforts on collecting data on the usage of information and communication technologies, there has been a considerable effort to develop a policy framework in terms of ICT information and communication technologies in Turkey. The meetings of Supreme Council for Science and Technology come to the fore. Those meetings were used to hold once in a year at the beginning. Currently, it is being held twice a year. This shows that those documents of meetings play a crucial role in determining the science and technology policy strategy of the country.

2.2. Information and Communication Technologies in Policy Documents

In Turkey, policies targeting ICT are designed at the Supreme Council for Science and Technology meetings. The use of information technology was more important than producing or improving these technologies at the early meetings. There were some problems that impede the advancement in ICT such shortage of human capital, lack of legal framework, imperfections in the capital market, lack of standards, and inefficiency in the public procurement. This section elaborates these policies from a historical point of view.

The Supreme Council for Science and Technology Reports

The Supreme Council for Science and Technology was established in 1983 to provide guidance to the government to determine the science and technology policy of Turkey. The first meeting of the council was held in 1989 and a set of decisions were taken concerning Science and Technology Policy of Turkey. Policies targeted information and communication technologies were at the initial stage and they were much concern about *building up telecommunication infrastructure*. A set of supporting instruments such as attracting foreign capital, increasing the share of R&D expenditure in GDP and tax reductions or exemptions for enterprises to increase their R&D activities, and increasing financial support for universities were started to be designed in this period.

At the end of the meeting, a set of future targets were put in place:

- To increase the number of R&D personnel (30 R&D personnel per 10000 population)
- To increase the share of R&D expenditure to 2 percent level of GDP in ten years
- Assigning research and development coordinators at ministery level
- Establishing new research and development centers, technoparks, laboratories to develop national expertise and metrology laboratory
- *Building up information systems infrastructure*
- Updating patent and intellectual property rights regulations
- A comprehensive approach should be developed to improve the international relations

The second meeting of the council was held in 1993. The document "Science and Technology Policy 1993-2003" was designed in this meeting. An additional report on informatics policy of the country has been documented. Accordingly, five strategic sectors are determined as an engine of growth and *information technology* is given a priority among them. To build up competence in information technology sector; facilitating human capital, promoting the use of information technologies under the leadership of public sector, preparing legal framework, and supporting R&D activities in information technologies are mentioned as main activities.

In Sixth Five-Year Plan (1990-1994), it was mentioned that the improvement of “software industry” in Turkey should be developed to have a competitive edge in the international markets. To achieve this goal, software projects enjoying this potential are determined and are supported by the government.

In those years, *the use of information technology* was more important than producing or improving those technologies and this point was emphasized in “Turkey: Informatics and Economic Modernization Report”, which was prepared by World Bank in 1993. This report put forward a shortage of human capital, lack of legal framework in terms of information technology, imperfections in the capital markets, a lack of standards, and problems in the public procurement.

Human capital

Human capital is the main source of ICT-led economic growth. In Turkey as emphasized in various policy documents, ICT sector is suffered from a shortage of human capital. In Izmir Iktisat Kongresi (DPT,1993), which was held in 1992, it was mentioned that, especially in the software sector, there is a strong need for technical staff. In addition, the organization of the labor in Turkey is not as developed enough to meet the demands of foreign firms in the field of ICT. Therefore, software outsourcing activity is not developed in Turkey(Worldbank, 1993).

There are also problems with formal education in the field of ICT. The education program for computer engineers is not compatible with the needs of the private sector. Firms tend to employee ICT specialists who do not have computer engineering formation. Therefore, formal education, especially for computer engineering programs, needs to be flexible which could be supported by the informal education centers or institutes. The number of computer programmers is not adequate which also harms the development of computer programs. Computer engineering programs are mostly based on the description of the work instead of coding.

Another problematic issue on human capital is related to the organization of workforce in the field of ICT. The computer engineers association has been established only recently[4]. For a long period of time, the Chamber of Electrical Engineers undertook this role.

Considering the current situation of ICT human capital in Turkey, recent evidence belongs to ICT Usage Survey of Business Enterprises. Only two waves, (2007 and 2008) have the question on the presence of IT personnel[5]. The question is "did you employ IT experts in 2007, January?"

In other waves, the question on IT expert is removed from the sample. Therefore, two waves (2007 and 2008) are combined and the final sample is about 1008. Although one year is a short term to make a robust evaluation, almost 40 percent of the sample follows ICT strategy depending on IT experts. However, there are some firms (N=125) that employed IT experts in 2007 but failed to follow this strategy in 2008. Looking at the composition of those firms, a majority of the sample is composed of larger

[4] The Computer Engineers Association was established in 2012, June 2 with considerable efforts of Electrical Engineers Association. There are three main motivations to establish a separate organization. First is the occupational mismatch. In Turkey, non-IT experts has been employed in the fields that require the expertise in IT. The second is the lack of job security as a result of " flexible working hours" and " workers mobility". The third is that in recent years computer engineers has been employed in non-engineering areas in Turkey.

[5] It is defined as people who have the ability to develop, operate, and maintain ICT systems. ICTs constitute the main part of their job (OECD,2011)

firms. Additionally, they tend to use specific technologies such as ERP. Another point is that firms (N=149) that do not employee IT experts in 2007, moved to the IT expert-led strategy in 2008. This may indicate a spillover effect for employing IT expert for those firms that decide on employing IT experts in 2008(see, Table 2.1).

Table 2.1. The number of IT personnel in the firm

	Did you employ IT personnel in January, 2008?		
		Yes	**No**
Did you employ IT personnel in January, 2007?	**Yes**	N=389	N=127
	No	N=149	N=273

Source: TURKSTAT (2007,2008).

Market Imperfections

Imperfections in capital markets generate serious problems especially for ICT-producing industries. The ease of copying or reproducing with minor changes on the product reduces the actual returns for innovating firms(Worldbank, 1993). There are different mechanisms to deal with market imperfection in Turkey such as standard setting and public procurement. Lack of standards is one of the problematic issues regarding ICT. According to Uckan (2009), the regulations on ICT have been delayed for a long time. To illustrate, Data Protection Law has not been enacted yet due to the problems related to meeting demands of several government institutions.

The second one is the public procurement which is important for Turkey since the first effort on improving ICT usage in the country started with public sector. However, there are also problems with effective communication through ICT tools between public sector and private organizations. Based on the results of the Use of ICT by Enterprises Survey, Turkey seems to improve its communication with public and private sector.

In the survey, there are three questions on communication channels between public sector and the private organizations. The first one is that did you use internet to communicate with public organizations?

The second one is that for what reason did you use internet to communicate with public organizations? Four main purposes are specified in the survey.

- To get information
- To download form
- To send information or document
- To bid electronically

The third question is that what are the barriers for using internet in communication with public organizations?

- Services are not available on the internet
- Face to face communication is much preferable
- Delay in returns for urgent issues
- Uncertainty about information security
- Extra costs of communication through internet
- Communication with public organizations is complicated
- Other reasons

Based on the responses, firms mostly prefer face to face communication based on the security concerns. This result also implies that the conventional view on online business is still valid.

Information asymmetries

Information asymmetry refers to the situation of which one of the agents has a deeper knowledge than does the other. Asymmetry between individuals or firms is linked to Williamson (1973). He argued that opportunism could be restricted if there is a high level of competition or information asymmetries are low.

As far as the link between information asymmetry and ICT is considered, it has been argued that the spread of ICT will reduce the knowledge and information asymmetries and transaction costs among firms and enhance the development of a competitive market. According to the development literature approach, there is a causal relation between high income groups and higher use of ICT. According to the assumption that advanced countries, because of the availability of resources, are able to use ICT technologies. Lutz(2003) found that besides income, institutional environment plays a crucial role in diffusion such as trade policy, political rights, and civil liberties.

The third meeting of the council was held in 1997. A set of key concepts as "*information society*" and "globalization", "innovation capability" ,"national innovation system", "national science and technology policy" were introduced in the report. The focus was on the term of globalization which has gained importance with the Final Act of the Uruguay Round[6].

[6] Uruguay Round is subject to criticisms since it is part of the liberalization process in the telecommunication sector. According to the argument, adapting S&T policies of developed nations to developing countries may not give similar results due to the incomplete liberalization. Therefore, with Uruguay Round and following activities state and the society play passive role in policy making while private sector undertakes a decisive role.

[6] "The European Research Area is composed of all research and development activities, programs and policies in Europe which involve a transnational perspective. Together, they enable researchers, research institutions and businesses to increasingly circulate, compete and co-operate across borders. The aim is to give them access to a Europe-wide open space for knowledge and technologies in which transnational synergies and complementarities are fully exploited. Launched at the Lisbon European Council in March 2000, the creation of a European Research Area was given new impetus in 2007 with the European Commission's Green Paper on ERA. In 2008, the Council set in motion the Ljubljana Process to improve

With the globalization, the spread of the multinationals throughout the world and technology transfer mechanism from multinationals to developing or underdeveloped countries have increased. Therefore, the report of the third meeting focused on how to design a national innovation system that attracts the multinationals to the country.

During these meetings, following actions are noted:

- *Building up national informatics infrastructure*
- Building up national academic network and knowledge center
- *Setting up e-commerce network*
- Preparation of Law of Technology Development Center
- Managing sources of brain power
- Supporting academic work in the field of social sciences
- Preparation of law of Turkey Accreditation Council
- Restructuring of public research organizations
- Construction of a separate national research and development budget
- Regulations on government support to R&D
- Dissemination of venture capital
- Technological or innovative Support to small and medium scale firms
- Industry-university collaboration centers
- Multi-Purpose Operational Sattelite Station

The problem was not the absence of policies targeted science and technology but the implementation of these technologies systematically. The Seventh Five Year Development Plan (1996-2000) was designed in the frame of "Breakthrough in Science and Technology Policy Project (Bilim

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the political governance of ERA and adopted a shared ERA 2020 vision. Concrete progress is being made via a series of new partnership initiatives proposed by the Commission in 2008" ve Teknolojide Atılım Projesi)". Promoting training activities to build up human capital in this industry was determined as a human capital policy towards ICT while the strategic importance of ICT with emphasis on the software component was mentioned as in the previous plan.

The forth meeting of the council was rather an assessment of the actions that were taken in the previous meeting. The national information infrastructure (TUENA 1996-1999) was at the center of the report. In addition, with the coordination of Ministry of Transport and public and private sector representatives, the necessity of establishing a council being responsible for the actions on information technology, was mentioned at the meeting.

TUENA Report (1996-1999)

Turkish National Informatics Infrastructure Master Plan (TUENA) is the pilot project for Vision 2023 Strategy Document which is prepared with the coordination Ministry of Transport and TUBITAK was in charge of secretarial tasks. Main goals of the TUENA Project were to determine the country's potential in the field of ICT, the main trend in the world, domestic demand in science and technology (S&T), capabilities that could help building up technology infrastructure, and the type of institutional setting required to reach these goals.

The first one with emphasis on the ICT potential of the country was measured by mobile phone usage. Based on the survey results, low income groups and high income groups differ in terms of telephone usage. In general, low income groups concentrated in rural area tend to use mobile phone for simple functions such as calling or messaging while other functions are used by high income groups. Based on the results of TUENA Report, council decided to prepare the National Science and Technology Policy Document: 2003-2023 at the sixth meeting. A separate report on ICT was prepared in this document. Therefore, the results of strengths, weaknesses, opportunities, and threads (SWOT) Analysis in 2023 Vision:

ICT Panel Report (2004) could be summarized as:

- Communication infrastructure such as telephone network centrals is well built in Turkey
- Expertise in hardware, design, production processes
- The presence of qualified workers
- Expertise in consumer electronics
- Young Population

A separate ICT panel meeting was held in 2004 of which results rely on participants' perceptions. Table 2.2 shows the strengths, weaknesses, threats and opportunities in the field of ICT. Cultural barriers still remain as a weakness despite the emphasis on openness to innovate in the society in the meeting.

Adoption capability of workers is high but ICT sector is subject to a gradual change, so adoption capability should be kept alive through continuous and informal training.

Two strategic sectors such as defense and medical electronics are equipped with experience and knowledge in the field ICT. However, they should be supported by an appropriate marketing strategy.

Microelectromechanical Systems (MEMs) applications have started only recently but Turkey has two research laboratories in this field with a number of researchers at graduate level and the country has gained a significant level of experience and knowledge. With the help of MEMs technologies, country could move towards technology producing stage rather technology user. However, these efforts could not turn into competitive gains in the international markets without an effective marketing strategy and a long term planning.

Another point is that there are some organizations that raise the firms' awareness about strategic planning and provide technical support to the firms. On the other hand, those S&T policies are designed in a general manner, which do not respond to the specific needs of the firms.

The term quality has gained importance in recent years but the number of brand producing firms in the field of ICT is quite few.

Table 2.2. SWOT analysis on ICT in Turkey

Strenghts	Weaknesses
• Opennes to innovate • Experience and expertise in the field of ICT,especially in Microelectromechnanicl Systems (MEMS), Microelectronics, • Cryptology, and Genetic algorithms • Adoption capability of workers to the new rules or institutions introduced by the technology • Presence of strategic sectors such as defense industry • Growth potential of medical electronics sector • Presence of institutions such as TTGV and TİDEB which guide firms to design strategic plans and create awareness of how firms benefit from support mechanism • Increasing awareness of quality in production	• Myopic approach towards long term planing and the lack of strategic thinking • Lack of marketing strategy • Lack of informal training programs • in the field of ICT • Cultural barriers towards creative thinking • Lack of teamwork • Limited sources of capital (in most cases, firms are forced to sustain themselves with their own financial sources) • Lack of specific policies in the sector • Lack of R&D investment • Absence of brand-producing strategy
Threats	**Opportunities**
• International monopolies • Mismatch between national and international regulations • Availability of cheap labor in countries such as China and India • Brain drain • Bureucracy • Economic crisis, low purchasing power, uneven distribution of income • Bad governance (corruption) • Market immaturity	• Growth potential of the sector • Skilled labor • Presence of the support mechanism towards sector • Presence of markets for ICT goods and services • Experience in e-government applications • Cheap Labor • Turkish population abroad

Note: Adapted from Vision 2023 Technology Foresight Project, ICT Panel Report, 2004, p. 14-16.

According to the results of the ICT Panel, Turkey is supposed to become an attractive country in three subfields of ICT. A set of policy tools such as using domestic and foreign capital to produce technology, collaborating with international business partners, and building up creativity in the society is determined to become a technology producer. In addition, facilitating domestic production as well as offshoring services which could not be produced in the country, and strengthening human capital infrastructure are mentioned as the main strategies for ICT-led economy in the panel meeting.

In 8th meeting of Science and Technology Supreme Council[7], the focus was on participation to EU framework programs and preparation of national science and technology policy: 1993-2003 Strategy Document.

The main actors in participation to 6th EU Framework Program were TUBITAK, Ministry of Foreign Affairs, and Ministry of Public Finance, The council of Higher Education, EU General Secretariat, State Planning Organization, and Under Secretariat of Treasury. In 6th Framework Program, facilitating *knowledge based economy* and *knowledge society* are mentioned as the main strategies to increase the ICT related employment and to sustain the economic growth in EU countries. Set of strategic technology fields are determined to accomplish these targets. *Information society technologies* and citizens and governance in the knowledge based society are two of them which are related to this study.

Since 2000, the impact of efforts for EU membership on science and technology policy of the country became much visible in policy documents. In the 9th meeting of the council, to create a national research area as similar to European Research Area[8] (ERA) was decided and three dimensions of this formation was highlighted. The first is integration among R&D activities, targeting complementarity among different components of the R&D system. Therefore, organizations with different specializations integrate their activities through a national R&D system. Efforts on encouraging participation to EU framework programs have started to succeed the integration policy. The second dimension is strengthening

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[7] In the document of 8th meeting, the term information is translated as "bilişim" and knowledge based society"is translated as " bilgi toplumu". This usage is similar to the recent use.

[8] The European Research Area is composed of all research and development activities, programs and policies in Europe which involve a transnational perspective. Together, they enable researchers, research institutions and businesses to increasingly circulate, compete and co-operate across borders. The aim is to give them access to a Europe-wide open space for knowledge and technologies in which transnational

research, development, and innovation capability of the organizations. The third dimension is building up innovation based approach in the society. The main shortcomings of the conventional view towards science and technology policy in Turkey were imitating what has already been produced and monitoring S&T activities of the other. Therefore, in the policy document, a strong emphasis was on technological innovation.

In the 10th meeting, an action plan of national science and technology policy (2005-2010) was prepared to design a S&T policy especially in the field of R&D for 2005-2010. Therefore, based on the results of vision 2023, a set of policies targeted R&D activities were put forward such as increasing the share of R&D expenditure in GDP by 2% and the number of researcher to 40,000 in 2010.

In the 11th meeting, council decided to determine the national science and technology performance indicators such as R&D expenditure, R&D researchers, patents, innovation in small and medium sized enterprises (SME's) and competitiveness. However, computer usage was not among these indicators.

In the 13th meeting, it was decided that national innovation performance indicators were decided to be collected. There is no emphasis on measuring information and communication technology of the country in this meeting.

Table 2.3. Efforts on collecting data on ICT

Survey	Institutions	Target Population	Result
Computer Usage Survey (1971)	TUBITAK and TURKSTAT	Enterprises	Sectoral variation in computer usage Computer usage is higher in services sector than that of manufacturing sector
Computer Usage Survey (1978)	TUBITAK Ministery of Development	Public and private organizations	Differences in ICT definitions
Survey on Informatics Services in Turkey (1980-1982)	TURKSTAT and METU	106 establishments in Informatics Services	The number of informatics services establishments has increased by 50 percent since 1980.Revenues from these services have doubled in the same period
Computer Usage Survey (1982)	TURKSTAT	345 Information Data Processing Centers	
Computer Usage Survey (1984)	TURKSTAT	689 Information Data Processing Centers	
Household Survey on ICT (1997)	TUBITAK	Survey was conducted in settlements with more than 20.000 population	Uneven distribution of computer ownership in the country in terms of income groups creates differences in ICT capabilities.
Households ICT Usage Survey (2005-2011)	TURKSTAT	Survey was conducted in settlements with more than 20.001 population	The difference between rural and urban households is small in terms of mobile phone ownership*.
Survey on ICT Usage in Enterprises (2005, 2007-2001)	TURKSTAT	10+ employees in selected sectors	Computer usage, webpage ownership, and internet access have increased from 2005 to 2011.

CHAPTER 3

A RETROSPECT ON FIRM LEVEL DETERMINANTS OF ICT ADOPTION BY ENTERPRISES IN TURKEY

3.1. Introduction

Adoption of ICT commonly refers to a decision in one point in time. This feature of the adoption underestimates the effect of time on decision. A firm may adopt technology in year t or it may delay the adoption until a date. Besides time, firm specific factors can affect the decision to adopt. Some firms cannot bear the the initial costs of adoption. The lack of financial sources or the absence of skilled personnel are such reasons that delay the adoption of the technology. This chapter provides a detailed analysis on theories of adoption as well as empirical literature on ICT adoption, In addition, methodologies used in the adoption literature are also applied to the firm level data which belongs to firms operating in manufacturing and services sectors in Turkey.

This chapter is composed of five parts. The first part elaborates the theoretical literature on adoption which can be grouped as classical adoption theories and contemporary adoption ones. The second part deals with empirical literature on the determinants of ICT adoption. These are specified as firm specific factors and environmental factors. The third part elaborates the methodology that is used to estimate ICT adoption at firm level. The forth introduces the data. The last part discusses the empirical results.

3.2. Theoretical literature on adoption

Adoption theories can be classified as classical adoption theories and contemporary ones (Attewell,1992) The first is closely linked to the diffusion side and its graphical representations while the second one focuses on the determinants of adoption. According to the internal influence model which is rooted in classical diffusion theory, firms that are connected to preexisting users of the innovation learn about the technology and adopt it earlier than the others who do not have such a connection. Therefore, firms delay in house adoption until they obtain sufficient know-how about the technology from prior adopters. This generates a knowledge barrier for potential adopters. Attewell(1992) argued that building up internal capabilities through imitation cannot be the only source of adoption.These capabilities are developed through external information channels. As for the external influence model, which is another angle of the classical diffusion theory, the interaction between prior adopters and potential adopters is not allowed. This implies that only common channels of communication such as mass media are used by the potential adopters. Therefore, the adoption process is driven by information external to the social system. The list of adoption barriers can be extended to the lack of innovation culture or the lack of flexibility in the production environment (Arendt, 2008). These barriers can also be established at an international level such as exchange rate volatility, tariffs, and quotas (Caniels and Verspagen, 2001). Contemporary diffusion theories focus mainly on those aspects of the adoption. It is built on a set of criticisms of classical diffusion theory. To illustrate, diffusion can be facilitated by nonmonetary factors such as institutional and market structures (Attewell, 1992) or managerial influences or workplace organization (Fichman, 1992). According to Attewell, classical diffusion theories ignore the difference between signaling and knowhow. In the classical adoption theories, signaling has the primary role in adoption because according to these theories potential adopters can only learn about the technology through signals from the users. This assumption underestimates the role of organization in the adoption. Accordingly, knowledge transfer from the originator to others does not provide a sufficient condition to adopt a new technology. It is rather determined by the user organization.

3.2.1. Classical Adoption Theories

The common idea behind these models is that the rate of diffusion is determined as the proportion of the number of potential adopters at a given time t. Therefore, the rate of diffusion of an innovation at any time t is a function of the difference between the total number of possible adopters existing at that time and the number of previous adopters. When the cumulative number of prior adopters approaches the total number of possible adopters in the social system, the rate of diffusion decreases. For the classical diffusion model, the rate of diffusion is proportional to the number of potential adopters at a given time t which can be expressed as

$$\frac{dN(t)}{dt}=g(t)(m-N(t)) \qquad (1)$$

Where N is the potential number of adopters at time t and m is the total number of potential adopters in the social system, g(t) is the coefficient of diffusion which is a function of previous adopters. N(t) can take the values to a range of zero and m.

Based on this equation, fundamental diffusion model can be classified as an external influence model and internal influence models. Dekimpe et al. (2000) use the terms demonstration and exogeneity for external and internal influence models. Two main effects are mentioned in that study. For the demonstration effect, the adoption time for any country is not independent from the others. As more countries adopt the innovation, costs of adoption decrease. Therefore, isolated economies tend to lag in adopting innovation. Exogeneity implies the presence of the exogenous factors such as country demographic factors, economic/political factors, and social factors that impact adoption.

The concepts of adoption and diffusion are in some terms used interchangeably. The distinction between adoption and diffusion is based on time dimension of the second. Thirtle and Ruttan (1987) made a distinction between the two by stating that adoption studies rather focus on "decision one point in time" and the factors that generate variation in adoption rates across users. Diffusion models, on the contrary, can be viewed as dynamic and aggregative processes over continuous time.

Early attempts at explaining adoption patterns are based on S-shaped curve representation. According to this, only a few members of the society are willing to adopt the technology in each time period. The number of adopters increases till the adoption curve reaches the highest point. This indicates that diffusion is complete.

3.2.1.1. S-Shaped Curve

The S-shaped curve shows the relationship between the cumulative adoption and the time. As shown by Figure 3.1, while a few members of the social system[9] adopt innovation in each time period, this rate increases, later; therefore, innovation is spread throughout a large population (Mahajan and Peterson, 1989). Finally, the diffusion curve slows down and after some point, it follows an upper asymptote of which the diffusion is complete.

The adoption curve has a unique distribution. Various factors such as the proportion of adopters in the previous period, profitability of the innovation, the amount of initial investment, and the industry determine the shape of the distribution. Accordingly, adopting innovation becomes less risky as the

[9] The concept of social system refers to the consumers, firms, or households. In fact, it is the organization or the bureaucracy that sets the standards and regulations of the system (Dekimpe et al., 2007).

information and experience are accumulated by the number of previous adopters. In addition, profitability is expected to have a positive effect on the decision to adopt. However, firms are reluctant to adopt a profitable technology that requires a large initial investment. Furthermore, there is a variation across industries in terms of adoption. Industries having competitive strength, qualified personnel, and financial advancement are more prone to adopt earlier than the others who do not have those assets. As a result, the slope may be steep at the initial stage or gradual based on these factors.

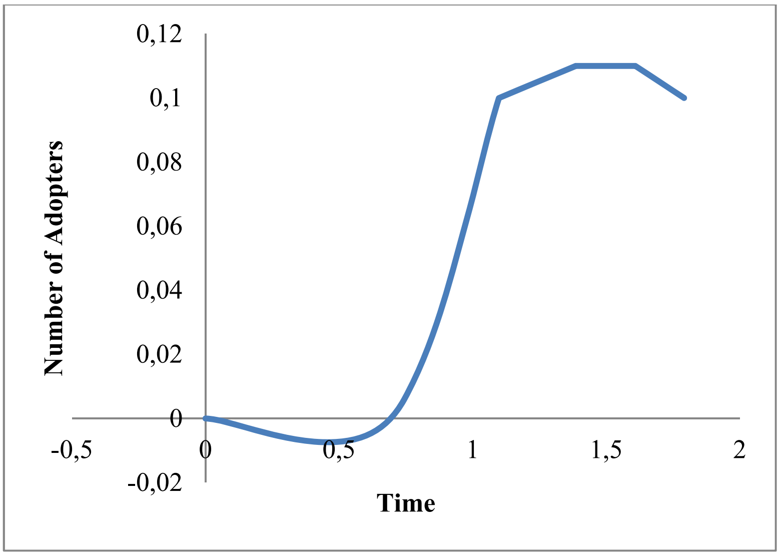

Figure 3.1. Cumulative Normal Distribution

3.2.1.2. Alternative explanation of S shaped Curve

Geroski (2000) developed an alternative explanation about the S-shaped curve. The emphasis was on the time of adoption. Accordingly, the diffusion rate of technology is slower for some firms than it is for others. Although the new technology promises a radical improvement over the existing technology, some firms are reluctant to adopt the new one. Therefore, adoption takes longer time. According to Geroski, the time lag for adoption is related to the time needed for awareness of the technology[10]. This was also discussed by Kalish (1985). Accordingly, consumers buy the product when they are aware of the technology. Additionally, if the risk adjusted price falls below their reservation level, adoption becomes faster. Hence, the number of potential adopters of the technology is measured as the risk-adjusted price multiplied by the percentage of the adopters who are aware of the technology. Based on this, the time path of technology diffusion can be observed through estimating the time required for the spread of information from one individual to another.

Accordingly, the main weakness of the S-shaped curve is that it does not explain the diffusion of an innovation from the date it is invented. Instead, it starts with some early users of the innovation. Therefore, the greater the number of users who have been built up, the faster is the diffusion. In addition, characteristics of innovation determines the distribution curve, therefore, the S-shape is not the only alternative.

Hall and Khan (2003) emphasized two mechanisms such as adopter heterogeneity and learning to explain the dispersion in adoption times. Based on the heterogeneity model, different individuals place different

[10] This is the early criticism based on the S-curve representation of adoption. There are some other factors that affect the the time of adoption. One is the trade off between the price of the technology and the profitability (Gopalakrishnan et al., 2003). Delay in adoption might also depend on the type of the technology. To consider the internet technology and its use for the banking transactions, the adoption time is shorter since it does not require a large capital investment.

values on the innovation. The distribution of the values on the new product tends to be normal. However, Peterson (1973) argued that when a new technology is introduced by the firm in a competitive industry,other firms may not be able to adopt the technology. Therefore, the distribution curve could be more peaked or skewed than normal distribution. To illustrate, the adoption pattern of generic technologies such as TV has a non normal distribution.

Similarly Geroski (2000) suggests that adoption differs in terms of the type of the technology. The slope of the adoption curve of hardware is much steeper than that for the adoption curve of the software. For the software adoption, potential adopters learn from previous users which require a certain amount of time. As shown by Figure 3.2, hardware adopters follow the A curve and software adopters follow the B curve. Therefore, hardware adopters can be classified as the first movers while software adopters are latecomers.

Figure 3.2 also corresponds to the combination of external influence models and internal influence models which are analyzed by Mahajan and Peterson (1989).The concave curve refers to the external influence model while the convex curve refers to internal influence model. These terms are discussed in detail in the following parts.

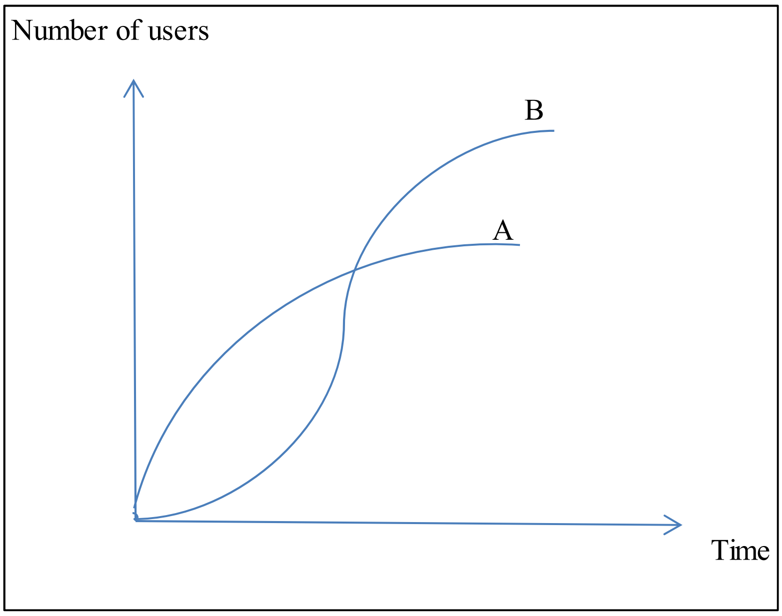

Figure 3.2. Diffusion of Software and Hardware
Source: Mahajan and Peterson (1989)

3.2.1.3. External influence model

The external influence model is based on the idea that the diffusion process is triggered by the information external to the social system (Mahajan and Peterson, 1985; Loh and Venkatraman et al. 1994). Therefore, the rate of diffusion at time t is a function of the potential number of adopters in the social system. In other words, the interaction between prior adopters and potential adopters is not allowed in the external influence model which implies that the number of adopters in the social system are isolated. This model cannot be applied when innovations are complex or that require interpersonal communication.

In contrast to the internal influence model which is based on the imitability of the resources, the external influence model assumes "imperfect imitability of the resources". This assumption is built on the resource based theory (Barney, 1991). According to this, three features of firm infrastructure which cannot be substituted perfectly are the main sources of competitive advantage. The first feature is the valuability which offers strategic opportunities to the firm. Uniqueness is the second feature which refers to product/service characteristics being rare to find among existing or potential adopters. The last feature is the imperfect imitability referring to the presence of technologies which cannot be copied easily by the other firms. The link between the external influence model and the resource based theory is established within the framework of the resource strategy which fits the environmental conditions of the firm.

The link between innovativeness and external influence is established in the innovation literature. According to this, innovators are affected by mass media or by external influences (Midgley and Dowling, 1978) while imitators are influenced by word of mouth[11] (Mahajan et al., 1990). In addition, Zmud (1983) found that in the software industry, innovativeness can only be improved upon in the presence of external information. The internal environment of the firm such as size, professionalism, task complexity, and context supports this mechanism through searching appropriate external information channels. On the other hand, if the firm is not innovation oriented, the external links are unnecessary. For software firms, the core teams which develop software and provide technical support tend to use the internal sources of the firm rather the external ones (Allen et al., 1979). Technical support groups mainly focus on the implementation of the activities in a quick and cost effective manner. Therefore, their motivation is not to find new ways of improving work methods. According to Brancheau and Wetherbe (1990), external channels of information are more important at the knowledge stage while internal channels are used at the persuasion stage[12]. The idea is that once a new technology is introduced

[11] Mass media implies one way communication from government to society. Word of mouth indicates flows through communication with family and friends (Ju-Lee et al., 2002).

[12] According to Rogers (1983), knowledge stage refers to the awareness of the potential adopters about the technology. Persuasion stage reflects the attitude of the potential adopter towards the technology.

by the firm, other firms which are exposed to this new technology become aware of it. At the persuasion stage, on the contrary, potential adopters can reflect their attitudes towards adopting the technology. As a result, earlier adopters tend to use external information while late adopters rely on interpersonal communication.

Venkataraman (1992) used the external influence model to explain the multidivisional organizational structure (M-form) which is commonly observed in large organizations. This organization structure is composed of several semi-autonomous departments that are controlled by the central unit. The M-form structure was first developed by Chandler (1962) and Williamson (1975). There were two specific distinctions in terms of the organization structure before the Second World War. These were the U-form structure and the M-form structure. The Ford Company was managed by the U-form structure which is organized as specialized units accomplishing complementary tasks. By contrast, General Motors was organized as the M-form structure which is composed of self-contained units (Holian, 2011). As for the link between the M-form structure and the external influence model, the M-form structure requires access the external information sources while the U-shape model relies upon the performance of the past applications.

3.2.1.4. Internal Influence Model

In this model, diffusion occurs only through interpersonal contacts (Peterson and Mahajan, 1978; Rogers,1983; Loh and Venkataraman, 1992). Accordingly, diffusion is a function of interpersonal communication or social interaction between prior adopters and potential adopters in the social system. The internal influence model can be represented as $dN(t)/dt=qN(t)[m-N(t)]$where $N(t)$ shows the cumulative number of adoptions at time t, q is the coefficient of the internal influence which is greater than zero, m is the potential number of adopters in the social system.

Therefore, the diffusion path is determined conditional on pure imitation. It can be represented as $g(t)=bN(t)$ where b is the coefficient of imitation, N is the population and g(t) is the rate of diffusion. The increase in adoption is a function of preexisting adopters in the social system.

The internal influence model is most appropriate when an innovation is complex and socially visible, therefore, not adopting would be disadvantageous for the members of the social system. The effect of internal influence is much more remarkable when the social system is composed of relatively small and homogeneous groups. For such groups, information that is based on past experiences plays a crucial role in adoption.

Empirical evidence on measuring the effect of internal influence dates back to Griliches (1957) who examines the diffusion of hybrid seed corn in the United States. Accordingly, the diffusion of hybrid corns is hindered in some particular areas. The factors which account for the delay in adoption are differences in profitability which is a function of market density, innovation, and marketing cost. Mansfield (1961) examined twelve innovations that spread from one enterprise to another. He showed that the diffusion of those innovations is based on imitation. In addition, the rate of imitation varies among adopters. It may be higher in industries in which risk aversion is less, highly competitive, and financially successful.

3.2.1.5. Multi-innovation Diffusion Models

Peterson and Mahajan (1978) have identified four categories of innovation interrelationships. These are independency, complementarity, contingency, and substitutability. Accordingly, innovations are considered to be independent in a functional sense. However, adoption of one technology enhances the adoption of the others. ICTs enjoy those features of the multi-innovation diffusion models. To illustrate, ICTs can substitute other inputs or have positive complementarities with other inputs. On the other hand, those two features of ICT may not provide advantages for some firms. For labour-intensive industries, the substitution of ICT does not generate profit maximization. In addition, if there is a mismatch between skilled labour and the technology, the complementary effect of ICT disappears.

Independent: Innovations are independent of each other in a functional sense but adoption of one may enhance adoption of the others. Since adopters are not isolated, the transmission of knowledge from adopters to non-adopters is possible.

Complementarity: increased adoption of one innovation result in increased adoptions of other innovations. According to Gomez and Vargas (2012), the technology use is closely related to the presence of complementary goods in the firm. Complementarities are studied from the view of resources which implies that interconnectedness of resources should be understood in order to assess the quality of the services provided. Therefore, the incentive of firms to adopt new technologies depends on the amount of complementary resources that they possess.

Complementarity commonly refers to the situation in which the presence of one component of the system increases the returns of the other. Ashish and Gambardella (1990) found positive correlation among complementary activities which serve the same objective. This objective could increase the firm's performance at the micro level, while it could lead to a decision between welfare regimes at the macro level. Cassiman and Veugelers (2006) and Lokshin et al. (2008) found that internal R&D activities have a complementary effect on external R&D activities. The former helps building up of absorptive capacity to ease the adoption of the latter. Therefore, the coexistence of these components should support or facilitate knowledge business (Makri et al., 2007).

Two complementary effects of ICT are mentioned in the literature. The first one is the direct effect which is observed when the capital per worker increases with hardware, telecommunications system, and software investment. This process is referred to as capital deepening. During the period 1995-1998, the direct effect of ICT on average labor productivity became faster than those during 1990-1995. This is induced by a continuous decline in the computer prices and a high level of investment, especially in high technology assets and semiconductors (Jorgenson et al., 2000). Secondly, the indirect effect indicates changes in business processes with ICT use. Accordingly, the link between productivity and ICT is re-established through complementary organizational investments (Brynjolffson and Hitt, 2000). Therefore, literature on the complementarity of ICT focuses more on the combined effects of ICT and other inputs on the productivity of the firm. In some cases, these inputs could be workplace organization, new products and processes (Bresnahan et al., 2002; Arvanitis, 2005), human capital (Milgrom and Roberts, 1990; Hempell, 2003), capabilities (Zhu et al., 2004) and in other cases, external environment such as involvement of customers, suppliers, and business partners in the project team (Tambe and Hitt, 2011). In other words, the ICT-productivity link is shaped within the framework of the "complementary effect" indicating that ICT creates multiple effects as a single input.

As for the link between adoption and the complementary technologies, the literature rather engages in the time of adoption and the adjustment costs. Jovanovich and Stolyarov (2000) take the adjustment costs into account while explaining the adoption of complementary technologies. Their approach emerged as an objection to the view that firms simultaneously increase the quality of their complementary products. They claim that if the adjustment costs of the complementary inputs are not convex, firms may tend to buy the inputs at different times because cheaper inputs have more spare capacity which does not necessitate replacement for a long time.

In addition to the cost of inputs, heterogeneity among firms determines the differences in the adoption time. In some cases, profit maximizing behavior could make that difference while in the others, prior knowledge and the infrastructure may ease the use of advanced technologies (Hempell, 2003). Furthermore, the presence of a skilled workforce should be mentioned as another factor that explains the variation in adoption time. Well educated workers learn new tasks more efficiently by training. Plant age is also considered to affect adoption. There are two different assumptions on its effect. One assumption is that young plants adopt earlier than old ones and they are more prone to use advanced technologies (Baldwin and Sabourin, 2002). On the other hand, the role of experience in the acquisition of ability to use ICT makes old plants adopt faster (Baptista, 2000). However, Dunne (1994) found that, plant age is not a determining factor in early adoption. Therefore, both old plants and young plants use advanced technologies at similar frequencies. As for the firm size, Smith (2010) claims that in wholesale and retail sectors, cost savings are greater since large firms adopt complementary technologies earlier than their smaller counterparts.

Contingency: adoption of one innovation is conditional on the adoption of other innovations. As in the examples of compact disc software and hardware, the diffusion of one of these products depends on the other (Mahajan and Peterson, 1978; Bayus, 1987). The contingency factors include both internal factors and external factors. Internal factors can be top management support, top management risk position, and technological factors such as compatibility. External factors include competitive intensity, information intensity, and government support. It was found that internal factors play a greater role in the adoption of the internet when compared to external factors (Teo et al., 1998). In other words, adoption of the internet depends on the presence of an organizational infrastructure.

Substitutability: increased adoption of one innovation resulted in decreased adoption of another innovation. The substitutability between fixed telephone and mobile telephone services affected public policy in terms of the competition in the US during 2000-2001. Therefore, the effect of substitutability can increase based on the price and quality changes in one of the technologies. Investing in ICT may lead to substitution of ICT equipment for other forms of capital and labour (Chowdhury, 2006). For instance, narrowband technologies and broadband technologies can also be considered as substitutes. According to empirical evidence which measures the substitution effect between technologies, it is found that there is a substitution effect between internal research and development activities and openness to external sources based on the resistance from technical staff in some firms (Laursen and Salter, 2006).

3.2.2. Contemporary Adoption Theories

Contemporary adoption theories focus more on the mechanisms which affect the adoption decision. These mechanisms are closely related to the availability of firm specific factors such as the presence of qualified personnel in the firm. According to the empirical literature, "rank effects" and "epidemic effects" are the dominant factors which explain the adoption of new technology (Canepa and Stoneman, 2003). In order to elaborate on the effect of the firm specific factors in decision to adopt, we used these different frameworks in this thesis. Accordingly, rank effect is based on ranking adopters in terms of returns from adoption that are determined by the firm characteristics. To illustrate, large firms adopt new technology earlier than the smaller ones and the profitability potential arises from the heterogeneity in the adoption time (Hollenstein, 2004). Additionally, spillover effects from adopters to non-adopters can accelerate the adoption. These effects are covered by epidemic effects.

3.2.2.1. Rank Model

In technology adoption research, the rank model is mentioned to explain heterogeneity among firms. According to this assumption, returns from adoption differ based on the adoption time and the intensity. (Davies, 1979; Karshenas and Stoneman, 1993; Battisti and Iona, 2009). Therefore, firms that adopt the technology when the acquisition costs are below the reservation costs, gain the returns from the early adoption. As acquisition costs fall, the cumulative benefit distribution follows a diffusion pattern which is composed of early adopters achieving higher returns and late adopters achieving low returns.

The rank model places the user characteristics at the center while explaining heterogeneity in adoption rates. The main assumption is that differences in adoption rates are based on specific features. Accordingly, adopters are ranked in terms of their returns from adoption. These characteristics could be the firm size, firm status, financial resources, the technological knowledge, and the skill composition of the workforce (Haller and Siedschlag, 2011) or the qualification and skill structure (Bosworth, 1996). In the empirical literature section, we analyzed the characteristics such as firm size, prior knowledge, openness, purposes of ICT usage, foreign share, and human capital.

3.2.2.2. Epidemic Model

The epidemic model is built on the idea that the speed of use of a new technology is slow due to the lack of information available about the new technology. Accordingly, there are N potential users of a new technology, and each adopts the technology when he/she hears about it. At time t , y(t) firms have adopted and N-y(t) have not. A transmitter which contacts a % of the population of non-users, {N-y(t)}at time t over the time interval t increases awareness by an amount $y(t)=a\{N-y(t)\}\Delta t$ (Geroski ,2000).

According to this model, potential adopters in the social system may have identical tastes and the cost of the new technology can be constant over time. However, there is an information asymmetry among the adopters. Each adopter consumer learns about the technology from their neighbor. As the information spreads from one person to another, the number of adopters increases which leads to an increase in the rate of adoption. When the market becomes saturated, the rate of adoption decreases. This generates an S-shaped curve for the diffusion rate.

Griliches (1957) and Mansfield (1961) were the first studies that constructed two assumptions of the epidemic effect. First is that adoption occurs when the potential users learn about the presence of the technology. The second is that technology diffuses from one adopter to another through direct contact between them. The combination of two hypotheses generate the S shape curve. Therefore, the speed of diffusion is based on the frequency of contacts. The epidemic model is defined as

$$d_m(t)=\beta\left[\frac{m(t)}{n}\right].[n-m(t)]d_t \qquad (2)$$

m(t)indicates the number of firms having adopted by the time t while n is the number of firms in the industry. Based on this model, the number of adopters increases as the share of users in the industry increases (Mansfield, 1968). This model has some deficiencies such as underestimation of other factors that mitigate the risk of adopting a new technology. These factors might include other information channels such as advertising or changes in the technology, costs and profitability.

Intergenerational effects in diffusion have been studied only recently. Accordingly, the nature of the technology has the determining role in the adoption. Three factors as defined by Geroski (2000) are considered. These are the number of potential adopters, the number of actual adopters in the previous period, and a multiplier. Liikanen et al. (2004) measured those three effects. These are penetration rate for the first generation mobile technology (1G), and penetration rate for the second generation mobile technology, and penetration rate for the fixed line. Whether or not there is a network effect or substitutability among these technologies are analyzed in their study. Based on this, within the same generation as in the case of 1G and 2G technologies, network effects play a crucial role indicating that relatively old technology has a positive effect on the diffusion of the new .

Geographical proximity also plays a crucial role in the diffusion of information from non-adopters to adopters. It facilitates imitation among firms through networking. On the other hand, the effect of geographical proximity can create substantial effects depending on the sources of technical knowledge and the characteristics of the industry (Baptista, 1999; 2000).

3.2.2.3. Stock and Order Model

Stock effects are first mentioned by Reinganum (1981). It is referred to as the "game theoretic approach" (Karshenas and Stoneman, 1993). Accordingly, as the number of previous adopters increases, marginal adopters have fewer benefits from the technology acquisition. In other words, the profitability of adoption at a certain point in time is negatively related to the extent of diffusion in the previous period(Hollenstein, 2004).

Order effects indicate the firm's position in the order of adoption. High-order adopters achieve a greater return than low-order adopters. The firm's decision to adopt depends on whether or not early adoption increases the profits. In the next section, empirical literature on determinants of decision to adopt are analyzed in detail.

3.3. Empirical Literature on determinants of ICT adoption

Understanding the pattern of ICT adoption requires detailed analysis of both organizational characteristics of the firm. Firm size, prior knowledge, openness functionality, human capital, foreign share, and organizational environment are mentioned as the main components of organizational characteristics. This section elaborates the empirical literature on the effect of those variables.

3.3.1. Firm Specific Factors

The role of firm specific factors on adoption is based on the argument that heterogeneity among firms is the source of higher returns from the new technology (Davies, 1979). According to this, resource heterogeneity determines the differences in adoption time, therefore, firms having strategic resources adopt earlier than the others and gain the early returns of adoption. In some cases, firm size could make that difference while in the other cases, prior knowledge may ease the adoption of those technologies. A long list of resource variables are included in this thesis which are, firm size, foreign share, openness functionality, prior knowledge, purposes of internet usage, human capital, and environmental factors.

3.3.1.1. Firm size

The size of the firm is the most frequently used variable in the adoption studies specifically for rank or probit models (Davies, 1979). The relationship between the size of the firm and the adoption is established based on costs. If adoption lowers average costs, larger firms will have a greater output in comparison to smaller firms. Early adoption is, therefore, more profitable for larger firms.

There is a considerable amount of literature which empirically found a positive relationship between firm size and ICT adoption (Fabiani et al., 2005; Baldwin et al., 2004; Delone, 1981; Morgan et al., 2006; Teo and

Tan, 1998; Thong, 1998; Morionez et al., 2007). On the other hand, the positive link between ICT adoption and firm size could be obscure in the presence of other factors which impedes the adoption. Information flow is faster in an environment where the managerial layers occur at a minimum level and the internal organization is based on team work. On the other hand, the scale advantage could emerge with the standardization of procedures and information which is crucial for adoption.

Firm size is determined by the number of employees in the organization or firm turnover. Fabiani et al. (2005) used the annual turnover to proxy firm size and have found its positive effect on some particular technologies. While the size of the firm is not significant for PC per employee, it generates positively significant effect for ICT expenditure per employee in favor of white collar workers. According to this, firm size matters when ICT includes different bundles such as purchasing and maintenance for training and consulting. In addition, firm size has more prominent role in selling products to other companies (B2B) and distributing products to consumers (B2C). This effect is based on network externalities[13].

3.3.1.2. Prior Knowledge

Why do some organizations discover some opportunities of early adoption and not others? Organizations need prior knowledge to assimilate and use the new technology. This process is defined as absorptive capacity (Cohen and Levinthal,1990). It shows the firm's capacity for learning, implementing new knowledge, disseminating new knowledge internally, and making use of new sources, including new technologies. Besides firm specific factors such as firm size and input costs, Corrocher and Fontana (2008) found that previously adopted technologies and equipment increases the benefits of ICT adoption. Attewell (1992) argued that firms delay in

[13] The concept of network externalities, in terms of technology adoption, refers to a change in the benefit or surplus that an individual or firm derive from a good when the number of adopters or users of the good increases.(learning by interacting)

house adoption of complex technology until they obtained sufficient technological know-how to implement and operate it successfully.

The provisions of intangible outputs such as quality, convenience, variety, or timeliness represent major reasons for investing in computers. These types of benefits are difficult to include in price indices (Boskin et al., 1997). Firms that invest more in computers than their competitors should achieve greater levels of intangible benefits such as prior knowledge. On the other hand, prior knowledge can create information asymetries among firms (Shane, 2000). Firms having related knowledge and experience adopt the technology much easier.

3.3.1.3. Openness Functionality

Openness functionality implies the trade openness of the firm and it can be measured as the sum of exports of products and services. Whether or not a firm that operates on the international markets can affect the adoption decision is the focus of this section. There could be different motivations for the link between adoption and exporting behavior in that sense. The first is to access broad knowledge through external links according to which a firm learns about the new technology earlier than the other firms (Hodgkinson and McPhee, 2002).

The second can be that the content of the business with international partners may require the adoption of the new technology. To illustrate, if the exported product or service is technology oriented and the exporting relationship is continuous, the exporting firm is forced to adopt related technologies to produce and export a much more advanced product or service.

The third is international competitive pressure. Accordingly, the presence of competitors in the same sector could enhance the adoption and the intensity of use of new technologies (Fabiani et al., 2005; Hollenstein, 2004).

Hall et. al. (2003) argued the role of trade openness in technology adoption in terms of the learning effect. Trade openness is not limited to the exports of high technology products, it should include imports from developed countries because only a few number of firms in the developing countries are able to export high technology products. According to this, high technology imports from developing countries generate transfer of knowledge to developing countries.

International competitive pressures, which may enhance the adoption and the intensity of use of new technologies are captured by the share of annual turnover due to export activity (Fabiani et al., 2005). Openness to international trade can also be measured as the ratio of the sum of exports and imports to GDP in world prices (Baliamune-Lutz, 2003). Hollenstein (2004) used exports to proxy the role of the firm in the competition and found positive effect of exports on ICT adoption.

3.3.1.4. Purposes of ICT Usage

This section elaborates on the effect of the purposes of ICT use. Empirical literature on the effect of purposes of ICT use is shaped in the cost-benefit framework. According to this, if a technology promises a reduction in the costs or increases in benefits, then adoption of the technology becomes easier.

The empirical evidence on the effect of the purposes is recent (Hollenstein, 2004; Baldwin and Rafiquzzaman, 1998; Arvanitis and Hollenstein, 2001; Arvanitis et al., 2002). Hollenstein (2004) used the term “objective of ICT usage”, and analyzed the effects of quality improvement, cost reduction, and input improvement on adoption. Arvanitis and Hollenstein (2001) used cost reduction, higher flexibility, improving product development, better product quality, securing technological need to explain the motives for the adoption of the advanced manufacturing technologies. Baldwin et al. (1998) mentioned the cost-benefit framework to understand the motivation for adopting specific technologies. Therefore, awareness of the benefits of the technology increases as more information is provided through different channels such as suppliers, trade relations, subsidiaries, university, and government laboratories. The time lag between awareness and the implementation of the technology depends on the firm's characteristics.

Arvanitis and Hollenstein. (2001) added competitive pressure to the list of objectives of ICT use. According to this, adoption varies among firms based on how they perceive competitive pressures (Majumdar and Venkataraman, 1993). He found negative effects of competitive pressure on adoption.

E-training and e-banking activities can also be used as purposes of ICT usage. As for the e-training activities, a firm may use the internet for the purpose of internal training or job-on the training. This generates two effects. The first is the human capital enhancement. The second is the cost saving. Therefore, a firm does not have to allocate a large amount of money for training outside the firm. Similar advantages are also supported by e-banking activities. The use of internet for those activities generates a reduction in transaction costs for the firm.

3.3.1.5. Foreign Share

The role of foreign share on ICT is mainly studied from an economic development perspective. Firms that are exporters or have foreign ownership are relatively heavy users of ICT regardless of the size of the firm (Qiang et al.2006). Foreign capital can be a powerful channel for the transmission of technology to developing countries by financing new investments, by communicating information about technology to the domestic affiliates of foreign firms, and by facilitating the diffusion of technology to local firms. Foreign investors bring both equipment and know-how.

As for the link between ICT adoption and foreign share, we should consider the effects of knowledge flows transferred from foreign firms to domestic counterparts. Under what conditions do foreign owned firms or firms with a relatively high percentage of foreign shares choose to transfer part of its activities to domestic firms? There are three motivations for the movement of foreign capital into developing countries.

The first motivation is based on the low labor costs and the political environment of the developing country. If there are substantial differences in the costs of skilled labour between two countries, foreign firms choose to invest in the cheaper one. For developing countries, a major part of the empirical literature is in line with the positive effect of foreign share on ICT adoption (Moriones and Lopez, 2007; Luchetti and Sterlacchini, 2004; Hollenstein, 2004; Meng and Li, 2002) while in the other, no effect is observed (Haller and Siedschlag 2011). Foreign capital has gained importance in developing country economies by some international agreements. In China, the share of foreign capital has increased by 10 percent after the country signed an agreement with the World Trade Organization (WTO). This policy change gave the impetus to the transfer of more labor-intensive activities related to the production of electronics to China. Other political changes such as tax reductions in the developing country can also be counted as a pull factor the multinationals.

The second motivation is related to the feature of the technology. When outsourced activities do not necessitate technological expertise, a foreign capital does not generate the expected effect. In this situation, foreign firm allocates the resources to the activities which provide a comparative advantage. Therefore, the firm can attract a more highly skilled staff through investment in its core competences.

The third motivation is that exploitation of benefits from foreign capital is based on the match between the technology and the existing skills of the firm. If the developing country invests in learning the transferred technology through reverse engineering, it attracts more technology transfers from multinationals.

3.3.1.6. Human Capital

Human capital is emphasized to a large extent in the adoption literature, based on the evidence that complementarity between a skilled workforce and computers have reduced the demand for unskilled labour in US manufacturing (Griliches, 1979). Based on the skill biased technological change (SBTC) hypothesis, technical change is non-neutral with respect to labor which stimulates the demand for skilled labor. Therefore, technical change is non-neutral with respect to labour. Karshenas and Stoneman (1993) argued that the training costs of skilled labour could have a significant influence on the adoption decision.

The SBTC hypothesis is tested on the firm level (Katz and Autor, 1999; Acemoglu, 2002; Link and Siegel, 2003), industry level (Berndt et al., 1992; Berman et al., 1994; Autor et al., 1998) or plant level studies (Dunne and Schmitz, 1995; Siegel, 1998; Doms et al., 1997; Bresnahan et al., 2002). The common finding in these studies is that there is a strong link between wage inequality and skill differentials both of which sharply increased in the United States from the 1970s to the mid- 1990s. On the other hand, some of the literature found a modest relationship (Chennels and Van Reenen, 1997) or no relation between skill upgrading and technology use (Pavncik, 2003). According to this, the link between the demand for skilled labor and technological change is obscured due the unobserved factors such as worker ability (Dinardo et al., 1997).

More recent studies focus on skill biased organizational change (SBOC) which refers to the changes in the organizational structure such as total quality management systems, lean administration, flat hierarchies, and delegation of authority. Empirical evidence reveals that both technological change and reorganization were determinants of the skill bias (Falk, 2002; Piva et al., 2005). Furthermore, there is a strong link between skilled labour and organizational change. Accordingly, technology does not directly increase the demand for skilled labour. The change in the demand for skilled labour occurs through organizational change (Bresnahan et al.,2002).

Human capital is proxied by various indicators in the literature that focus on the link between human capital and adoption of ICT. Characteristics of labour such as educational level, age, training, the presence of R&D or IT personnel are commonly used as indicators of human capital.

There are different ways of measuring human capital. It can be proxied by education as mentioned in the literature (Luchetti, et al., 2004; Hollenstein, 2004; Fabiani et al., 2005; Lutz, 2003). Luchetti and Sterlacchini(2004) used two proxies. One is the percentage of employees with a university degree and the second is the percentage of employees with secondary education. Their effects on different proxies of adoption are positive in most cases.

Human capital can also be measured by the R&D on effort at the establishment level which provides a measure of the firm's capability for processing new technological information at a minimum cost, as argued by Cohen and Levinthal (1989). R&D activities indicate the capabilities in absorbing the new knowledge. In our study, we use R&D personnel expenditures indicating both skill and R&D activities. R&D activities are used as indicators of the firms' capabilities in absorbing new knowledge.

In the empirical literature, a positive effect of research development activities on the decision to adopt is established by (Bosworth 1996; Arvanitis and Hollenstein 2001; Faria et al,. 2002, 2003; Barbosa, and Faria, 2008).

Age composition of the employees can be used as a proxy for human capital. Empirical evidence on the effect of age is threefold. The first is that the older the employees, the greater the likelihood for the ICT adoption. Morionez and Lopez (2007) used the share of employees below the age of 30 in order to test the stimulating effect of age on adoption and found that the effect of younger population in the firm is negative for users of the extranet technology which is widely used in the services sector by multinationals. This result is strongly linked to work experience. Therefore, older workers with adequate knowledge and expertise are able to adopt the technology faster than younger colleagues who do not have similar experience. The second evidence, on the contrary, provides a positive association between the presence of young workers and technology adoption. Meyer et al. (2011) has found that firms with a greater share of employees younger than 30 are much more able to adopt the technology in comparison to firms with a higher share of employees older than 30. This evidence is also supported by previous studies in the literature.The third evidence indicates insignificant effects of age on adoption (Fabiani et al., 2005; Maliranta and Rouvinen, 2004; Nishimura et al., 2004). In the presence of other proxies of human capital such as wage flexibility or the number of white collar workers, the effect of age is obscured.

3.3.2. Environmental Factors

With the rise of knowledge based economy, transmission of knowledge among individuals or organizations became less dependent on geographical proximity which is still a controversial issue since some regions are more innovative than others. Freeman (1991) mentioned "selection environment" to conceive the processes that promote the survival of innovative firms. Selection can occur at various levels such as the level of R&D projects in the R&D system, the level of the individual within the firm, the level of the firm itself, or the level of the industry or region. This section examines the literature on the effect of region and the industry, which are labeled as environmental factors in this thesis. The question is through which mechanisms environmental factors could increase the pace of adoption.

3.3.2.1. Geographical Proximity

Geographical proximity is crucial in terms of three components. Firstly, a large part of production is concentrated in small areas. Secondly, firms in the same industry or specialized in similar technological fields are prone to locate in certain places. Finally, this tendency follows a sustainable pattern through time (Malmberg, 1996).

Alderman and Davies (1990) found that there are significant regional variations in the rates of diffusion of key manufacturing technologies. According to this, it is at the diffusion stage that the greatest impact of technological change upon economic growth is seen to occur. If a region lags behind in the invention or the adoption of new technology, it may face industrial decline. On the contrary, some of the literature that associates a positive link between adoption of a new technology and proximity emphasizes that the positive effect of geographical proximity is generally observed at the initial stage of adoption (Baptista, 2000). In addition, the learning effect is much stronger at that stage (Baptista, 2000; Hagerstrand, 1967; Lindner et al., 1982).

There are two main mechanisms used to exploit the benefits of proximity. These are networking and institutional environment. Networking effect which consists of lobbying activities and inter personal relations, is one of the mechanisms that makes proximity advantageous for agents. Tassey (1991) proposes that networking is essential for the development of a region's knowledge infrastructure. In fact, technology itself has strong network effects that positive feedback from early adopters facilitates potential adopters (Katz and Shapiro, 1986). Besides, region can play an intermediary role in the diffusion of the technology. Firms in the same location tend to connect each other which, in turn, triggers imitation process for latecomers. Gallaud and Torre (2005) emphasize that geographical proximity only influences the innovative performance of firms if there is effective interaction between the agents. In addition, Battisti and Stoneman(2003) mentioned the importance of external networks that transmission of knowledge from one organization to another is much faster than the transmission of knowledge within the firm.

The second mechanism is the presence of institutions that provides the related knowledge and financial sources. These can be established within the firm or outside the firm. Internal knowledge sources are regular training programs, the presence of IT and or R&D personnel, the level of education of the workforce, leadership, and work organization, while the external knowledge sources are technoparks, R&D centers, universities with expertise in ICT discipline, scientific and research council, NGO's, and public organizations.

As far as the network benefits are considered, availability of skilled workforce and transfer of knowledge can be counted as two of them. It is linked to the presence of qualified institutes, school or universities in the same geography that are compatible with the needs of the firms. For regional innovation, a high level of qualification of the labor force and highly publishing universities are the main determinants (Ronde and Hussler, 2005). As for the transfer of knowledge, Lundvall (1988) emphasizes that in the same geographical boundary, the transmission of a tacit knowledge from one firm to another is more likely to occur.

Regional differences in diffusion rates result from the geographical clustering of innovators and early adopters of new technology. Geographical proximity stimulates networking between firms, thereby facilitating imitation and improvement.

The model includes variables representing the regional density of adopters and technologically close firms, in order to examine the effects of the geographical environment on the speed of diffusion. It has been argued by Porter, 1990; Feldman, 1994; Baptista, 1999 and indeed empirically verified by Glaeser et al., 1992; Audretsch and Feldman, 1996; Baptista and Swann, 1996, 1998) that the geographical concentration of rivals enhances competitiveness and stimulates innovative activity, firm growth, and entry.

The transmission of new technological knowledge works better within geographical boundaries because this kind of knowledge has a tacit and uncodified nature (Lundvall, 1988). By following such a line of reasoning, one can claim that the diffusion of new technological processes may occur faster in geographical areas where the density of the sources of knowledge about such technologies is higher.

Early work on diffusion theory concentrated on epidemic, or learning effects by which potential adopters procure new technology upon receiving information about its existence.

Adoption is not a simple function of knowledge but requires also evaluation and trial. Much of the information necessary to support the diffusion of an innovation flows through personal contacts. Networks of interpersonal communication that link organizations developing and adopting technological innovations are of considerable importance in the diffusion process.

3.3.2.2. Industry Effects

The technical capacity of the industry in which the firm operates, also affects the rate of diffusion (Rosenberg, 1972). Industries can shape knowledge across firms. For the R&D intensive industries, the pace of diffusion was slower since private knowledge sharing is less likely in those industries (Appleyard, 1996). Therefore firms in industries which focus on “basic” research and are “demand driven”, are much more prone to share information (Von Hippel, 1988). Inter-firm mobility in the industry is one of the mechanisms that facilitates knowledge sharing (Almeida, 1996).

Industry is one of the components of the epidemic effect. In some studies, the Herfindahl index which shows that industry concentration is used in order to reveal the relation between adoption and concentration in specific industries (Haller and Siedschlag , 2011). He used the share of ICT adopters in the same industry. In the next section, methodologies on ICT adoption is discussed in detail.

Table 3.1. Review of empirical literature on the firm level determinants of ICT adoption

Authors	Level	Data	Measure of ICT	Method	Key Results
Fabiani, S., Schivardi, F., and Trento, S. (2005)	Firm	Manufacturing, 1475 firms in 2000	Three measures of ICT: hardware and software expenditure of ICT, network technologies related to internal organizational issues, and network technologies related to the use of internet	OLS and Ordered Probit	Specializing in mature industries Dominancy of small firms are main barriers toadoption Being organized around large firms Being in rural area is negatively correlated with ICT adoption
Giunta, A. and Trivieri, F. (2004)	Industry	Manufacturing industry 17000 small and medium size enterprises in 2001	Index of IT which ranges 0 and 3. It takes zero which means no IT adoption. 1=Firm has one or more personel computers 2=Firm uses e-mail address 3=using pc+e-mail+website	Ordered Probit	Age is negatively correlated with adoption
Haller, S. and Siedschlag, I.T. (2007)	Industry	Manufacturing industry 2001-2004	Five measures of ICT: computer usage, receiving orders via internet, index of services, share of employees using computer, share of sales due transactions over the internet	Probit and Fractional Logit	Significant differences between foreign and domestic firms regarding firm characteristics and adoption
Haller, S. and Siedschlag, I.T. (2008)	Industry	2001-2004	Inter-firm adoption which takes the value of 1 if the firm has a website ;doing online transactions, share of experts,share of sales due to online transactions	Probit and Fractional Logit	Positive technology spillovers from adopters to nonadopters
Hollenstein, H. (2004)	Firm	Business sector 6717 firms in 2000	Time period of ICT adoption and intensity of use of ICT	Factor analysis of ICT adoption	Positive effect of workplace organization on ICT adoption
Luchetti, R. Sterlacchini, A. (2004)	Firm	Manufacturing and business services in 1999	E-mail and internet,use of production integrating ICTs, market oriented ICTs	OLS and Tobit	Having website is positively correlated with highly educated workers

Table 3.1. Continued

Martins, F.O.M. and Oliveira, T. (2007)	Firm	Business Sector 2001	Broadband and IT skills	Linear regression and probit model	Age is negatively correlated with adoption
Moriones,A.B, Lopez, F.L. and Vasconcelos, G.C. (2005).	Firm	Business Sector 2002	Personal computers per employee, computer users, intranet, extranet, video conference,website ownership	Probit and Tobit estimations	Membership to a multinational ownership is strongly related to ICT adoption
Pohjola, M. (2003).	Country	Agriculture	Logarithm of computer hardware spending	OLS	Income is one of major determinants of ICT usage
Shiels,H.McIvor,R. And O'Reilly,D. (2003)	Industry	Services	Technical integration, operational integration,inter organizational integration and strategic integration	Case study	Sophisticated models of ICT use is important for services sector

3.4. Methodology on Firm Level Determinants of ICT Adoption

Firm level determinants of ICT adoption by enterprises in Turkey is analyzed by using different methodologies. These are ordered logit, logit and probit, and gllamm. In several studies, adoption indicates a decision point in time (Davies 1979; Galliano et al., 2001; Moriones et al., 2005; Haller and Siedschlag 2007). For most of these, logit or probit models are applied since the dependent variable is binary taking the value of one if the individual/firm is an adopter and zero otherwise. In some cases, the dependent variable is assigned to multiple categories and the values of each category indicates a sequential order (Giunta and Trivieri, 2004; Hollenstein, 2004). This is referred to as an ordered logit model. In this thesis, ICT adoption is measured on three levels. These are technology ownership model, ERP and CRM usage, and the use of narrowband technologies and broadband technologies. Technology ownership is estimated by ordered logit model while the other models are analyzed by logit and probit. Both cross section and panel analysis are conducted for those models in order to determine the optimal lag needed to introduce firm specific factors which in turn affects ICT adoption.

3.4.1. Ordered Logit Framework

In the first model, a technology ownership variable is created based on the assumption that having complementary technologies indicates ICT capability which helps firms carry on the activities more efficiently than the owners of a single technology. As shown in Table 3.2, enterprises are asked to respond to the following question that "Did your enterprise have the following technology in Jan, 2009". The choices are LAN (Local Area Network), Wireless LAN, intranet, and extranet. Response categories are "1" if the enterprise does not have any technology[14] or owns only one of these technologies. "2" represents the ownership of two technologies, "3"

[14] The number of non-adopters in the sample is too small and the estimation results did not change after they were removed from the sample. This category is combined with the single technology users.

indicates three technologies and "4" shows four technologies. As demonstrated in Table 3.2, two technology categories have the largest share and one technology category follows this. The smallest share belongs to the four technology category[15].

Table 3.2. Distribution of categories of technology ownership

Q: Did your enterprise have the following technologies in January, 2009?		
Response Categories	Freq.	Percent
1	1,001	27,55
2	1,296	35,67
3	768	21,14
4	568	15,63
Number of Observations	3633	100

Source: TURKSTAT (2009)

3.4.1.1. Cross Section Ordered Logit

The technology ownership variable is estimated by the cross section ordered logit model. Dependent variable comes from the Use of Information and Communication Technology by Enterprises Survey (2009) while the explanatory variables belong to the Annual Structural Business Survey(2007). The hypothesis is that firm specific factors have lagged effects on adoption[16]. Responses are based on their own declaration of the subject of the survey so that y^* is the unobserved technology ownership variable. Equation (3) shows that y^*varies in terms of changes in x_i which is a vector of explanatory variables. ε_i is an unobserved error term and independent of $x_{i.}$

Possible outcomes can be arranged as $y_{i=}$1,2,3,4}

[15] Considering the share of users for each technology, wireless LAN and LAN users dominate the sample while intranet and extranet usage stay between 15-21 percentage.

[16] Majumdar and Venkataraman (1993) explained the adoption level in 1978 by the variations in the explanatory variables for 1973.

$$y^*=x_i'\beta+\varepsilon_i \quad (3)$$

$$\Pr(y_i=m|x_i,\beta,\tau)=F(\tau_m-x_i\beta)-F(\tau_{m-1}-x_i\beta) \quad (4)$$

$$y_i=\begin{cases} 1\Rightarrow 1 \text{ if } \tau_0=-\infty\leq y_i<\tau_1 \\ 2\Rightarrow 2 \text{ if } \tau_1=\tau_1\leq y_i<\tau_2 \\ 3\Rightarrow 3 \text{ if } \tau_2=\tau_2\leq y_i<\tau_3 \end{cases} \quad (5)$$

In the presence of more than two categories, a multinomial logit can also be used. It is based on the estimation of binary logit for each outcome. Therefore, outcomes are categorized without any order such as colours of the umbrella; green, yellow, or brown. The occurence of each outcome is determined separately and each category takes the value of 0 and 1. In contrast to an ordered logit model, values do not rank from low to high. In addition, one category is determined as the base category in multinomial logit. Each category is evaluated according to the base category. The ordered logit model is used in this thesis because of these differences. In addition, the ordered logit model is tested against the multinomial logit model. Accordingly, Bayesian Information Criterion[17] (BIC) (Schwarz,1978) test result supports the ordered logit model (see Appendix 3).

In order to decide whether the ordered logit or the ordered probit model should be used, the LR test is applied for each model[18] (see, Appendix 4).

[17] Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) are formulated as BIC=-2log(L)+$k$log(n) ;AIC=-2log(L)++2k where k is the number of the parameters, n is the number of observations, L is the likelihood.The difference is based on the sample size (Wasserman, 2000).

[18] These two specifications give the similar results (Greene, 2004).The model selection could also be based on the distributional assumption on error term (Güngör, 2003). When a large number of observations located in the tails of the distribution, the logit model could be appropriate one. Ordered probit specification is based on the assumption that error term is normally distributed.

This method compares the log likelihoods of these two models. The STATA subcommand namely "omodel" is used to implement this procedure which gives chisquare estimation results for each. According to this, the result of the ordered probit estimation is very close to the ordered logit estimation. However, the first produces slightly larger coefficients than the second, therefore, the ordered logit model is used in this thesis. In addition, to check whether coefficients for some variables are identical, the Wald test is applied (Brant, 1990) (see, Appendix 5). The chi-squared of 52.42 for the Brant test is close to the LR test result.

3.4.1.2. Panel Ordered Logit

Panel data presents both inter-individual differences and intra-individual dynamics which generate several advantages over cross section or time-series data.

The first advantage is related to accuracy. In comparison to cross sectional data, more degrees of freedom and less multicollinearity are observed in the panel data. The second advantage is to obtain more information on an individual's behavior. To consider the difference between adoption and diffusion in this thesis, the former indicates a decision in point in time while the latter reflects a process. In addition, with panel data, it is possible to track sequential observations for each firm. In addition, Hsiao(2005) indicated that panel data provides the advantage of observing the before and after effects, which is crucial for policy evaluation. The third advantage is related to omitted variable bias which occurs in the situation of ignoring the effects of certain variables that are correlated with other explanatory variables in the model (Wooldridge, 2002). Assuming that y and $x \equiv (x_{1,} x_{2,...,} x_k)$ are the observable random variables. The term c which is an unobserved random variable is added to the vector. When it is rewritten as a linear model; $E=(y|x_1,x_2,...,x_K,c)$ assuming that c is uncorrelated with any x_j. Under the assumption of $\text{Cov}(x_j,c)$ is not equal to zero, putting c into error term could generate serious problems such as inconsistency in the estimation of β.

In cross section data, one solution is to find a valid instrument that is correlated with c. With the panel data, population regression function becomes

$$E(y_i|x_i.c)=\beta_0+x_t\beta+c \quad t=1.....n \tag{6}$$

where c is unobserved and time constant variable such as managerial influence, motivation or cognitive ability. The first differencing procedure could be applied to eliminate the unobserved heterogeneity. Variables $y=y_2-y_1$, $x=x_2-x_1$, $u=u_2-u_1$. The regression function becomes $y=x\beta|u$. Results of the first differencing procedure are based on standard linear regression (OLS). Orthogonality and rank conditions are required to consistently estimate β in OLS. The orthogonality condition is based on the assumption that explanatory variables and error term are uncorrelated $E(x`u)=0$. The rank condition is

$$\text{rank } E(x`x)=K \tag{7}$$

$$E\left[(x_2-x_1)`(u_2-u_1\right]=0 \tag{8}$$

$$E(x`_2u_2)+E\left(x`_1u_1\right)-E\left(x`_1u_2\right)-E(x`_2u_1)=0 \tag{9}$$

In panel data, zero correlation between the explanatory variables and the unobserved effect indicates random effects while this condition is relaxed in fixed effects. Panel data provides information on individuals and individuals over time which reduces the risk of omitted variable bias.

The forth one is that panel data includes dynamic relations. With panel data, it is possible to observe inter-individual differences to reduce collinearity between variables. Panel data includes time series observations for a number of individuals which is ideal for investigating the homogeneity issue versus heterogeneity issue. Panel data specification is used in order to control for unobserved hetereogeneity.

3.4.1.2.1. GLLAMM Specification

For panel ordered logit; generalized linear, latent, and mixed models (GLLAMM) are used in order to estimate multilevel latent variable models for responses including continuous responses, ordered and unordered or categorical responses (Rabe-Hesketh and Skrondal, 2008). Y^*_{it}=a+X_{it}β+ε_t

t=1,...,T; and i=1,...,N (10)

Y^*_{it} is a latent variable indicating technology ownership being composed of categories ordered as below

$y_1<y_2<\ldots<y_s$ where s=1,…,S (11)

The threshold model for each category is shown as

$$y_i=\begin{cases} 1 \text{ if } y^*_{ij}\leq K_1 \\ 2 \text{ if } K_1 y^*_{ij}\leq K_2 \\ 3 \text{ if } K_2<y^*_{ij}<K_3 \end{cases} \quad (12)$$

K variables indicate the threshold parameters, K_1 indicates a lower level while K_3 shows upper level. The response probabilities of the each category is X_{it} captures the firm level determinants of technology ownership, ε_{it} independent and identically distributed random variables a is intercept and β shows slope coefficients for the determinant variables.

For technology ownership model of which the dependent variable is an index of multiple technologies, GLLAMM procedure is applied to estimate panel ordered logit model. GLLAMM application is only available for random effects which are based on two strict assumptions. One is that unobserved effect is uncorrelated with the other regressors. The second one is regressors are uncorrelated with the error term.

As for the GLLAMM model, two specifications for the random effects are introduced. They are random effect for intercept proportional odds model and coefficient proportional odds model. Proportional odds model is modelling the dependence of an ordinal response on discrete or continious covariates[19] (McCullagh, 1980). For proportional odds model, the cumulative odds ratio for any two values of the covariates is constant across response categories. Assuming that Y is the response category ranging between 1 to k where k is equal or greater than two. The cumulative response probability is

$$\gamma_i = pr(Y \leq j|x) \qquad (13)$$

where j is the number of the category and covariate x is constant. For logistic model, both intercept and slope values depend on j categories as demonstrated by $logit(\gamma_j)=a_j-\beta_j^{\tau}x$. For proportional odds model, slopes are assumed to be equal and does not depend on j category.

The main idea for random intercept model is that the intercept is allowed to vary over firms. The main assumption is that the cumulative logit is normally distributed and independent across firms. For the latent response formulation,

[19] This term is used interchangebly with ordered logit.

$y^*=v_i+\varepsilon_i$ (14)

For random coefficient proportional odds models, both intercept and slope are allowed to vary across the firms based on the assumption that intercepts and slopes are independent across firms. In this thesis, the results of these two estimations are compared to in order to choose the appropriate random effect model.

3.4.1.3. Fixed Effect

For the random effects model, the unobserved effect is put into the error term assuming that there is no correlation between x_{it} and v_{it}. For fixed effect models, the correlation between the unobserved effect and the regressors is allowed (Wooldridge, 2002).

$y_{it}=x_{it}\beta+v_{it}$ (15)

$v_{it}=c_i+u_{it}$ where v_{it}=composite error term, c_i=unobserved effect, u_{it}=idiosyncratic error.

Therefore time constant factors such as industry or region[20] are not included in the term x_{it}. For fixed effects, the focus is the time varying factors.

There is no specification for the fixed effect in GLLAMM. On the other hand, Hove et al. (2011) introduced the first differencing methodology to eliminate the fixed effects in the model (See Table 3.3 for the different methodologies to estimate fixed effects).

[20] These factors could also be time variant but it is more likely to observe sectoral mobility than the shift from one industry to another.

3.4.1.3.1. Panel Data-First Differencing

First-differencing is used in order to eliminate unobserved heterogeneity and omitted variable bias. First differencing is the easiest way of dealing with fixed effects. However, there is no direct way of calculating fixed effects for the ordered logit panel data.

$$y_{it}=x_{it}\beta+\varepsilon_{it} \quad (16)$$

where the subscript i refers to the observation unit and t is the time period.

$$\varepsilon_{it}=\theta_i+v_t \quad (17)$$

θ_i is called a fixed or random effect that does not change over time. Even if θ_i represents unobserved determinants of y_{it} that are correlated with, it is possible to consistently estimate β by first-differencing the data.

$$y_{it-1}=x_{it-1}\beta+\theta_i+v_{it-1} \quad (18)$$

Taking the first difference;

$$y_{it}-y_{it-1}=(x_{it}-x_{it-1})\beta+(\theta_i-\theta_i)+(v_{it}-v_{it-1}) \quad (19)$$

or

$$\Delta y_{it}=\Delta x_{it}\beta+\Delta v_{it} \quad (20)$$

As a result, OLS gives consistent estimates for the β since θ is eliminated from the regression and Δv_{it} is uncorrelated with Δx_{it} because of the assumption that

$$E(v_{it}|x_{it})=0 \quad (21)$$

Table 3.3. Fixed Effect Ordered Logit Applications

<table>
<tr><td rowspan="5">Fixed Effect Ordered Logit</td><td rowspan="3">Technology Ownership</td><td>Gllamm -First Differencing (Hove et al.(2011)</td></tr>
<tr><td>Ferrer-i Carbonell and Frijters (2004) Estimator</td></tr>
<tr><td>Baetschmann et al. (2011) The Blow-up and Cluster Estimator</td></tr>
<tr><td>ERP and CRM</td><td rowspan="2">Panel Logit</td></tr>
<tr><td>Broadband and Narrowband Technologies</td></tr>
</table>

In the literature, a few studies use fixed effects discrete choice models (Manski, 1987; Charlier et al., 1995). Recent applications are fixed effects binary logit models. There are different formulations to solve the bias estimation of beta when the study is based on short panel (Greene, 2004). The first one is to collapse dependent variable into binary level. Chamberlain (1982) developed an estimator to elaborate the fixed effects. In order to estimate Chamberlain's model, a cutoff point k is chosen. Similarly, Winkellman and Winkellman (1998) analyzed the relationship between unemployment and happiness by using German Socio-Economic Panel for the years 1980-1990. The dependent variable in their study which is satisfaction has an ordinal scale ranging from 0 to 10. To estimate the fixed effects ordered logit model, the dependent variable is separated into two categories referred to as satisfied and dissatisfied. There is no prior condition from which to choose the cutoff points. As a result, the pooled ordered logit model is compared to the fixed effects binary logit model. The same procedure is applied by Schwarze (2003) which analyzes the determinants of income satisfaction. Satisfaction is an ordered response variable that is reduced to a binary response by grouping variables in terms of below and above the satisfaction point. In the model, the pooled ordered logit, the pooled binary logit, and the fixed binary logit are compared. According to this, the pooled ordered logit model and the pooled binary logit give similar results implying that the pooled binary logit could be an appropriate model.

These studies are based on Chamberlain (1980) which uses a single cut off point to obtain the binary dependent variable. More recently, alternative methods have been developed such as Ferrer-i Carbonell and Frijters (2004) and Baetschmann et al. (2011). In the first one, an "optimal" cut point is defined for each individual based on the individual level mean or median of y_{it}. The Hessian matrix is calculated for different cut off points. The optimality condition is based on the minimization of the Hessian matrix for each individual. Baetschmann et al. (2011) developed the alternative estimator namely the "BUC" estimator. While collapsing the dependent variable, different cutoff points were used each time.

3.4.1.3.2. Ferrer-i Carbonell and Frijters(2004) Estimator

Studies on measuring the level of happiness lead to attempts to find an alternative indicator for ordered logit fixed effects. Accordingly, for a period time, happinnes has been used to be treated as a cardinal variable meaning that the difference in happiness between 4 and 5 for any individual is the same as between 7 and 8. In addition, studies on the cardinal scaling of happiness are based on the assumption that the changes in happiness are affected the changes in observables. In order to control time invariant observables, Ferrer-i Carbonell and Frijters (2004) proposed the fixed effect ordered logit model which is similar to the Chamberlain (1982) fixed logit model. Accordingly, each category is treated as a binary variable to estimate fixed effect ordered logit, therefore, only a single cut off point is applied to all the cross-sectional units.

Ferrer-i Carbonell and Frijters (2004) proposed an estimator where the optimal cut off is defined for each individual. The optimal cut off is one that minimizes the individual Hessian matrix at the preliminary estimate of beta. According to this, they have found a small difference between the results of OLS estimations and fixed effect ordered logit results but they introduced the effect of time invariant factors related to observables in their model.

3.4.1.3.3. The Blow up and Cluster Estimator

Baetschmann et al. (2011) developed an alternative method to estimate the fixed effect ordered logit model. The estimator is referred to as “blow-up and cluster” (BUC). They argued that the Chamberlain (1980) type of solution results in a loss of information (Baetschmann et al., 2011). The main motivation for developing the BUC estimator is to explain the negative effect of unemployment on life satisfaction which is measured at ordinal scale. They assumed that this adverse effect might be due to the time invariant factors. In this methodology, standard errors are clustered as some individuals contribute to several terms in the log-likelihood function. This estimator does not suffer from the problems associated with cut offs resulting in a small sample.

3.4.2. Logit

Logit models and probit models are the most frequently applied models when the dependent variable is a dichotomous variable taking the value of 0 and 1 (Amemiya,1981).

$P(y_t=1)=F(\beta^{`} x_t)$ where $x_t$ is a vector of constant and unknown parameters.The common form of function is $F$ is $\varphi(\beta^{`} x_t)$ and φ is the standard normal distribution function and Logistic $L(\beta^{`}x_t)$ where $L=\{1+\exp(-x)\}^{-1}$.

$$
\begin{aligned}
&y^*=\beta^{`}x+\varepsilon \\
&y=1 \quad y^*>0 \qquad\qquad (22) \\
&y=0 \quad \text{otherwise}
\end{aligned}
$$

As for the panel specification, logit model which is conditional on maximum likelihood (ML) provides consistent estimates for large N and small T. This condition is based on fixed effects which are not possible with the probit model. Therefore, for the analysis of the fixed effects model, the logit model is the appropriate one (Maddala, 1987).

3.4.3. Conclusion

In this thesis, ICTs are evaluated at three levels. These are ownership, usage, and investment. In order to reveal the effect of firm specific factors on technology ownership and usage, ordered logit and logit models are applied. For the ordered logit models, technology ownership index which is composed of multiple technologies, are created in order to analyze the effect of firm specific factors while advancing from a single technology to multiple technologies. This hypothesis is conditional on the presence of complementarity among technologies. Both cross sectional and panel estimates of the ordered logit models are implemented. Fixed effect ordered logit applications are more recent and they focus on health (Böckerman and Hecer, 2009), satisfaction (Schwarze, 2003), and happiness (Winkellman and Winkellman, 1998). In these studies, the ordered response variable is collapsed into the binary category by using a single cut off point (Chamberlain, 1982). More recent studies developed alternative cutoff points determined at an individual level mean (Ferrer-i Carbonell and Frijters, 2004)

As for the level of usage, ERP and CRM technologies as well as narrowband and broadband technologies are analyzed by using logit models. ERP and CRM technologies work on different principles; therefore, these technologies cannot be used interchangeably. According to this, firm specific factors generate differential effects on each technology. This hypothesis is based on the term of specificity, implying that each technology serves specific purposes.

Narrowband technologies and broadband technologies can be arranged as simple and complex technologies. ISDN technology belongs to the first group while mobile connections and other fixed connections are in the second group. All these variables are estimated by using the logit model due to the binary nature of the each variable.

3.5. Data

This section examines the sources of the data, construction of the variables, and the data cleaning procedure. Two data sources are used in this thesis. One is the survey of "Use of Information and Communication Technology by Business Enterprises[21]". The other is the survey of "Annual Structural Business Statistics".

In this thesis, the determinants of the ICT adoption at firm level are analyzed by using both the cross section and the panel data. Cross section analysis is conducted by using the 2009 wave of Use of Information and Communication Technology by Business Enterprises Survey and the 2007 wave of Annual Structural Business Statistics Survey. Panel data analysis is

[21] The term " enterprise" is used in the Methodological Manual for Statistics on the Information Society by Eurostat. According the definition, "The enterprise is the smallest combination of legal units that is an organizational unit producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources. An enterprise carries out one or more activities at one or more locations. An enterprise may be a sole legal unit."

estimated by using the 2007-2011 waves of the Use of Information and Communication Technology by Business Enterprises Survey and the 2003-2007 waves of Annual Structural Business Statistics Survey.

3.5.1. Sources of Data

Use of Information and Communication Technology by Business Enterprises Survey

Efforts on measuring information society which targeted both enterprises and individuals were started in 2002 with the assistance of the European Commision. With the regulation No 808/2004 which was adapted in 2004 by European Parliament, it was decided that ICT surveys should be revised in terms of the changing needs of the enterprises and the individuals. Based on this regulation, from one year to another, new questions are added while others are removed from the survey.

The Use of Information and Communication Technology by Business Enterprises Survey was first conducted by the TURKSTAT in 2005[22] based on the methodology developed by Eurostat. The survey includes information on the use of computers, internet and other ICT technologies, and the technological qualification and integration. Specifically, questions are based on the ownership of technologies such as LAN, WLAN, intranet, extranet, website ownership, access to internet, broadband and narrowband connections, e-commerce, e-business, e-government applications, and ICT security.

In 2007, the Address Based Population Registration System (ABPRS) was established aimed at recording all Turkish citizens. There were some differences in the distribution of population by age, sex and regions in the ABPRS when compared to previous censuses. Therefore, new population

[22] The basis of the survey dates back to 1980s . More detailed information is elaborated in Chapter 1.

projections were produced according to the new system. The third wave of the survey which was conducted in 2008 was designed in accordance with the methodology introduced by Eurostat, and was published right after the second wave. The third wave of the survey which was published in 2009 was the revised version of the previous survey and the scope was extended. In this survey, banking, financial leasing and insurance operations of firms were included for the first time. Therefore, the third wave of the survey is used in the cross section estimation of ICT adoption.

As for the data collection methodology, TURKSTAT followed a stratified random sampling[23] which is based on the economic activities and enterprise size [24]. Economic activities are classified in accordance with NACE Rev.2. The sample consists of enterprises with 10 or more people employed. As for the geographical scope, enterprises operating in any region of the country are included in the survey. The target respondent is the director who is in charge of IT-related issues in the firm. For small enterprises, the respondent can be anyone from the managerial unit.

Annual Structural Business Statistics Survey

The very first effort to collect data on industy in Turkey dates back to 1917. Ten years later, the first Annual Manufacturing Industry Statistics Survey was conducted on firms which were included in the Legislation of the Encouragement of the Industry Law and the establishment of Industrial Corporations (1927). The survey was implemented on this basis until 1941. Since 1992, data has been collected on a yearly basis.

[23] In stratified random sampling technique, the population is divided into subgroups which are named as strata. The combination of the strata gives the whole population. For each stratum, sample is drawn independently and the collection of these samples constitute stratified sample.

[24] Size classes are grouped as small, medium-sized and large. 10–49 persons are employed in small enterprises. 50–249 persons are employed in medium-sized enterprises. 250 or more persons are employed in large enterprises.

In 2002, the Annual Structural Business Statistics Survey was designed in accordance with the European Council Decision No 58/97 in 20/12/1996 and 295/2008 in 11/03/2008[25]. The full enumeration method is used for enterprises with more than 20 employees. The stratified random sampling is applied to the small enterprises and the compromise allocation methodology is followed in that procedure[26].

The survey is composed of questions on employment, working hours, personnel costs, social security costs, expenses, income, inventories, turnovers, exports and imports of goods and services, fixed capital investment, sales, and depreciation. In addition, the distribution of capital as foreign, private, and government owned, expenses on research and development activities are also included in the survey. Research and development activities are decomposed into R&D personnel expenditure[27], R&D investment, internal and external R&D expenditure.

3.5.2. Data Matching Procedure

To make a cross section analysis, the Use of Information and Communication Technology by Business Enterprises Survey (2009) was matched with the Annual Structural Business Statistics Survey (2007).[28] Dependent variables to estimate the ICT adoption are generated based on the former. Independent variables are introduced in the model with a two-year lag[29]. A set of hypothesis is constructed based on the literature which

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[25] The aim was to revise the survey in accordance with the EU standards on firm competitiveness and performance.

[26] The compromise allocation methodology is a combination of Neyman allocation and proportional allocation models. The basic idea is to increase the efficiency of the stratified sample mean.

[27] This variable is used to proxy human capital in this thesis.

[28] After this year, some questions on exports and imports of goods and services and, R&D activities are removed from the questionnaire by TURKSTAT.

[29] Majumdar and Venkataraman (1993) also used lagged variables.

examines the impact of firm specific factors on ICT adoption (See Table 3.12). Specifically[30];

H1: Firm size- The effect of scale economies exists before the technology is adopted.

H2: Initial software investment- Organization needs prior related knowledge and infrastructure gained through software investment to assimilate and use the new one.

H3: Export Share and Export Share Square- Firms learn the new technology from foreign counterparts through exporting activities. Learning new technology requires time which in turn generates positive effects on adoption. On the other hand, the effect of export share on adoption is U-shaped which turns negative after a certain point.

H4: Research and Development Personnel Expenditure- Developing certain skills to adopt a new technology requires time, therefore, investing in R&D personnel has lagged effects on adoption.

H5: Foreign share- The presence of foreign owned firms easies the access to the external network. On the other hand, this effect is not observed immediately.

As for the panel data analysis, five waves of Annual Structural Business Statistics Survey and Use of Information and Communication Technology by Business Enterprises Survey are matched using common firm id numbers (see, Table 3.4). The total number of common firms in the dataset is 322.

[30] E-banking and e-training activities belong to the Use of Information and Communication Technology by Business Enterprises Survey(2009).

The survey period includes 5 years. Therefore, the total number of observations is 1610[31].

There are two main motivations to use panel data analysis for ICT adoption in this thesis. The first is to reveal whether the impact of firm specific factors on the adoption of different levels of the technology remain the same in the long term. While cross section analysis treats adoption as a decision in one point in time, panel data analysis mainly engages in the diffusion side. Thus, these two analyses provide a comprehensive perspective in terms of adoption and diffusion. The second one is related to the duration of the time lag. For the panel data analysis, a four-year lag between dependent variables and independent variables is introduced while a two-year lagged effects of firm specific factors on ICT adoption is analyzed in the cross section analysis. The discussion on the time lag for adoption dates back to Jensen (1982). Accordingly, a number of scenarios can be considered to determine the adoption time. The first is that a firm may adopt the technology immediately after building up the infrastructure. According to the second scenario which is based on the uncertainty, a firm may choose to wait and monitor the behavior of its rivals. Therefore, learning over time decreases the uncertainty. These scenarios refer to "the optimal stopping problem" which can be solved by using optimal rule. Therefore, if the posterior estimate of the likelihood of profitability is sufficiently high, a firm can adopt the innovation. In this process, Jensen (1982) mentioned the importance of the firms' initial assessments on innovation. The more optimistic the initial belief is, the more favorable the information is received. In this thesis, the focus is mainly on the impact firm specific factors on adoption since there is no information on the perception of the firms in the survey.

[31] Balanced data is applied in this thesis since the focus is to analyze the diffusion pattern of the firms .

Table 3.4. Data Matching Procedure for Panel Data

Waves	Annual Structural Business Survey	Information and Communication Technology Use by Enterprises
	Dependent Variables	Independent Variables
	2011	2007
	2010	2006
	2009	2005
	2008	2004
	2007	2003

3.5.3. Detecting Outliers

As an attempt to detect the outliers in the data, the residuals which are defined as the difference between the model's predicted outcome and the observed outcome for each observation in the sample, were examined to evaluate the model fit (Cook, 1977). Therefore, an index plot is constructed to detect the residuals by plotting them against the observation number, then, it is sorted according to the firm size so that observations are put in order from small firms to large firms. Furthermore, the number of observations which may be influential on the sample were detected. As shown by Figure 3.3, Cook's distance statistics test results indicate that there are a number of observations which may affect the further steps of the estimation negatively. Five observations which fall into the second area on the figure are dropped from the sample and the estimation is replicated, but there has been no change in the results. Therefore, these observations which may have the probability of being influential are tolerated in this thesis.

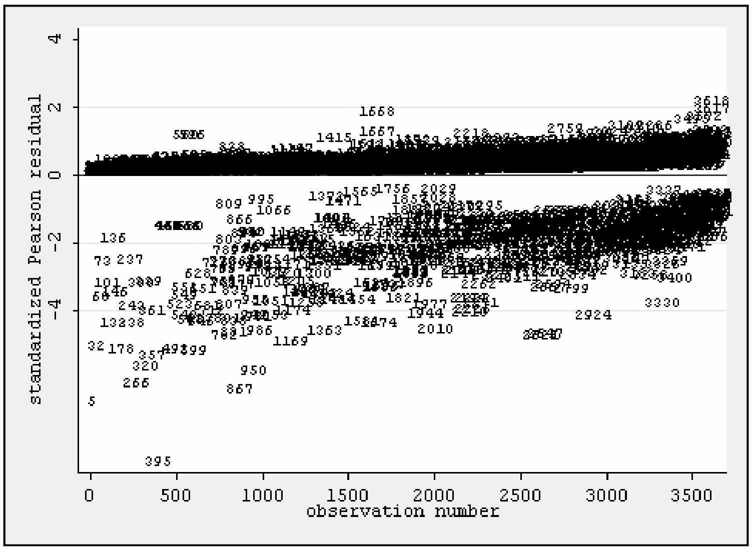


Figure 3.3. Plotting Residuals with Observation Numbers

3.5.4. Construction of Adoption Variables

In this part of the thesis, two different databases are used in order to construct the related variables. These are the Annual Industry and Service Statistics (2007) and the Use of Information and Communication Technologies by Enterprises Survey (2009). All dependent variables are derived from the latter. According to the classification of Wirthmann (2008) based on the Eurostat ICT Usage Survey Methodology, ICT usage indicators separated into 4 categories. These are making investments in ICT research, adoption of ICT by businesses, e-commerce, and e-business. Adoption of ICT by businesses is measured as computer usage, the presence of intranet, extranet, and free operating systems in the firm. Receiving orders online or purchasing online are sub-variables of e-commerce. Lastly, e-business activities include links of internal and external processes, use of CRM, e-invoices/ signatures, and secure transactions. Based on the data availability, only two categories; adoption of ICT and e-business activities are used in this thesis.

The first variable is technology ownership which ranges from 1 to 4. It is constructed based on the question as to whether or not the enterprise has such technologies as Local Area Network (LAN), Wireless LAN, Internal Communication Network (Intranet), and External Communication Network (Extranet) in January, 2009. Local Area Network (LAN) connects computers and devices in a limited geographical area. Having a LAN connection, which is referred to as production integrated ICT, links the intra-firm processes to the interfirm operations (Luchetti and Sterlacchini, 2004). A wireless connection is a system in which a large number of computers are connected to the network. Each technology has different superiorities from one to another. To demonstrate, LAN provides a faster and more secure connection when compared to WLAN while the latter is advantageous in that users are able to connect to the network at different points. Internal communication network (Intranet) is used to enhance knowledge sharing within the firm. It coordinates the intrafirm activities and employees interact with each other through this system. Additionally, this type of network not only connects the local computers and networks but also the other external networks through the gateways. Extranet is mainly used to communicate with customers and other firms. The idea behind using intranet and extranet are similar but they differ in terms of the content of network usage. Most of the knowledge on the extranet carries the codified notion while the knowledge sharing mechanism works in a firm-specific setting in the intranet.

In the questionnaire, each variable is asked separately. An index is constructed by using these variables. The reason for creating the index is based on the hypothesis that the more variety of technology a firm has, the more advanced the level of adoption. For instance, having/using intranet only shows the internal communication of the firm while using both intranet and extranet offers a system which manages the internal operations on the one side and coordinates the external organization on the other. Hence, it is assumed that technologies in the index are complementary to each other and the presence of these technologies simultaneously offers a desired situation in comparison to the situation of which one technology is available. According to this, the variable technology ownership takes the value *1* if the firm only uses one of these technologies. If two technologies are owned by the firm then the variable takes the value *2*. It becomes *3* if three technologies are used. Finally, if the firm has all the technologies specified in the question, then the technology ownership variable takes the value *4*.

Table 3.5 shows the mean of each variable with respect to technology ownership. According to this, large firms are more likely to adopt advanced technology. The same effect is observed in other variables. Differences are closely observed after moving to the stage where three technologies are applied.

Table 3.5. Distribution of Some of Explanatory Variables into Technology Ownership

Technology Ownership *	Firm Size	Export Share	Foreign Capital	R&D
1	4.56	0.07	1.6	0.001
2	4.93	0.09	3.33	0.005
3	5.44	0.12	9.96	0.007
4	5.83	0.14	15.43	0.02
Total	5.07	0.1	6.14	0.007

*1= one technology ownerhsip;2= two-technology ownership; 3=three-technology ownership, 4= four technology-ownership.See Table 3.11 for the definitions of the variables

Source:TURKSTAT(2007a).

The second group consists of CRM and ERP.CRM is a system which is used for collecting information about customers and integrating this information into the firm's processes. It places the customer at the center of the firm's activities. In addition, this system introduces internet and software skills in order to coordinate relations with the customers. ERP application targets the efficient use of firm specific factors such as labour, machinery and equipment.

In the third group, connection types such as ISDN, Other Fixed Connection, and Mobile connection are analyzed. Each variable is estimated separately because the approach which is applied to the case of technology ownership is inappropriate for the connection types. These technologies are arranged from old technnology to new technology. The reason for using these variables is to reveal if firms differ in the use of old and new technology.

Table 3.6 demonstrates the use of narrowband technologies and broadband technologies between 2005 and 2012. The first point is that some of the variables are removed from the survey while new variables are added in this period. Until 2008, traditional modem and ISDN were asked separately. The second is that questions related to mobile connection and the use of 3G technology were added after 2009 since these technologies did not exist in the previous years.

In Table 3.6, the transition from narrowband technologies to the broadband technologies can be observed. The use of traditional technologies decreased from 2005 to 2012 while the ADSL technology was a dominant technology between 2005 and 2009. After that, the use of mobile technologies gained impetus. In 2011, the use of 3G technology for laptops increased almost 50 percent. Based on the S-shaped curve, when 3G technology was introduced, only a small proportion of the enterprises adopted it (12,9 %) and but it jumped to 22,2 % the next year. These percentages are similar for the use of 3G technology on mobile phones.

Table 3.6. Type of Connections (%)

Narrowband			Broadband				
Years	Traditional Modem	ISDN	DSL	Other fixed connections	Mobile connection	3G on laptops	3G on Mobile phones
2005	35,3	6,8	79,7	9,4	*	*	*
2007	18,4	3,8	94,2	10,1	13,6	*	*
2008	16,1	3,7	95,3	8,1	13,8	*	*
2009	19,5		94,6	10,2	13,5	*	*
2010	18,0		87,3	15,5	11,1	12,9	11,0
2011	22,0		89,0	17,7	13,2	22,2	20,4
2012	11,1		87,9	35,0	15,1	27,5	24,3

Source: TURKSTAT (2005-2012).

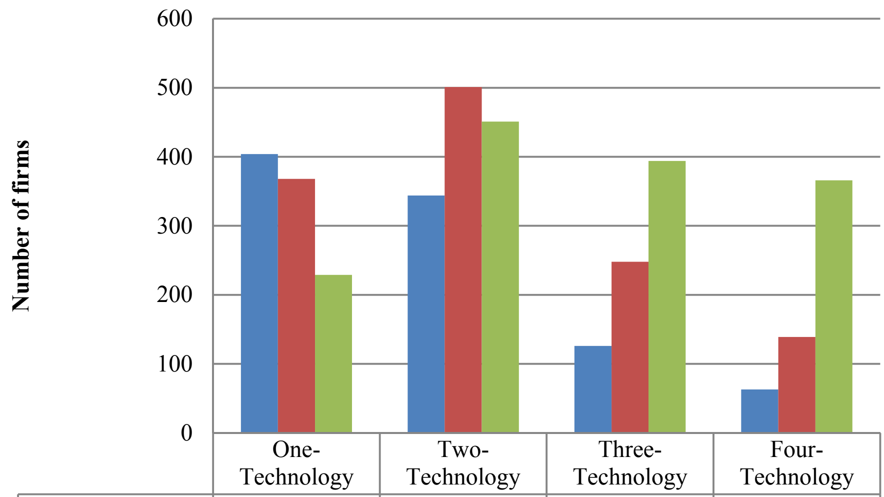
Explanatory variables in this thesis consist of firm size, human capital, foreign share, exports, purposes of internet usage, industry, and region. Firm size which is frequently mentioned in the technology adoption literature is calculated as the logarithm of the average number of employees. As shown in Table 3.7, the proportion of enterprises having websites increased between 2005 and 2012. Looking at the distribution of website ownership for each size group, small firms lagged behind the medium sized firms and the large firms. On the other hand, the largest growth in the proportion of website ownership between 2005 and 2012 is observed for these firms.

Table 3.7. Proportion of enterprises which have website/home page by economic activity and size group through years(%)

Years	Size group			
	Total	10-49	50 - 249	250 +
2005	48,2	43,3	70,9	90,5
2007	63,1	60,6	71	80
2008	62,4	58,4	74,4	86,6
2009	58,7	55,2	76,7	84,8
2010	52,5	48	73,9	87,3
2011	55,4	51,2	71,7	86,0
2012	58,0	54,2	74,6	88,3

Source: TURKSTAT (2005-2012).

In the cross sectional estimation of ICT adoption, the 2009 wave of the Use of Information and Communication Technology by enterprises survey is used (see, Figure 3.4). Looking at the spread of technology ownership for each size group, the share of small firms is the highest for the one-technology owner group. As for two the technology owner group, the number of medium sized and large firms has the highest share. Furthermore, in the three technology owner group and the four technology owner group, the number of large firms is less than that of the other groups but they dominate these two technology groups. In addition, the differences among technology groups in terms of firm size are significant.



	One-Technology	Two-Technology	Three-Technology	Four-Technology
Firm Size <50	404	344	126	63
Firm Size >=50	368	501	248	139
Firm Size >=250	229	451	394	366

Figure 3.4. Distribution of technology levels through firm size
Source: TURKSTAT (2009).

The second indicators and the third indicators are export share and foreign capital. Firms that are exporters or have foreign ownership are relatively heavy users of ICT regardless of the size of the firm (Qiang et al., 2006). The presence of foreign owned firms can be a powerful channel for the transmission of technology to developing countries by financing new investments, by transferring information on the technology to the domestic affiliates of the foreign firms, and by facilitating the diffusion of technology to local firms. Foreign investors bring both equipment and know-how. In this thesis, the share of foreign owned firms is 9 percent of the sample. In contrast to the argument that establishes no relationship between firm size and foreign ownership, a majority of foreign owned firms is composed of large firms (see Table 3.8).

Table 3.8. Distribution Foreign Ownership through Firm Size

Foreign Ownership	Firm Size			Total
	<50	>=50	>=250	
0	914	1176	1222	3312
1	23	80	218	321
Total	937	1256	1440	3633
Pearson chi2(2) =127.8759 Pr = 0.000				

Source: TURKSTAT(2007)

Table 3.9 displays the distribution of the purposes for internet use by the enterprises between 2005 and 2010. The purposes for internet usage are composed of four variables; e-banking, e-training, market monitoring, and receiving digital goods or services. E-banking activities include the financial activities being implemented through the internet such as online transactions and information acquisition from financial institutions. In addition, firms may use the internet for educational purposes with the help of e-training applications. However, the internet is predominantly used for the purpose of banking and financial services. The questions on market monitoring and receiving digital goods or services have been removed from the survey in different years. Hence, these variables are not included in this thesis.

Table 3.9. Distribution of Purposes of internet usage through years(%)

Years	Banking and financial services	Training and education	Market monitoring	Receiving digital goods or services
2005	75,4	34,3	67,7	38
2007	77,5	32,6	75,9	*
2008	77,6	33,4	77	*
2009	76,3	31,6	*	*
2010	78,1	28,3	*	*

Source: TURKSTAT(2005-2010).

The effect of industry and region dummies is also taken into consideration in this thesis. Seven industry groups are created based on the O'Mahony and Van Ark (2008) taxonomy which are mentioned as a) ICT Producing Manufacturing b) ICT Producing Services c) ICT Using Manufacturing d) ICT Using Services e) Non ICT Manufacturing f) Non ICT Services g) Non ICT Other (see, Table 3.12). However, the number of observations for each category is not represented so the even categories have been reduced to five categories. As a consequence, subsectors of each industry are combined regardless of producing or using ICT. Therefore, the categories are referred to as ICT producing and using manufacturing, ICT producing and using services, non ICT manufacturing, non ICT services, and non ICT other. In this model, ICT producing and using manufacturing represents the reference category.

Looking at Figure 3.5, ICT producing and using services and non-ICT manufacturing have equal shares in the sample. ICT producing and using manufacturing and non-ICT services follow these. Non-ICT other has the smallest share.

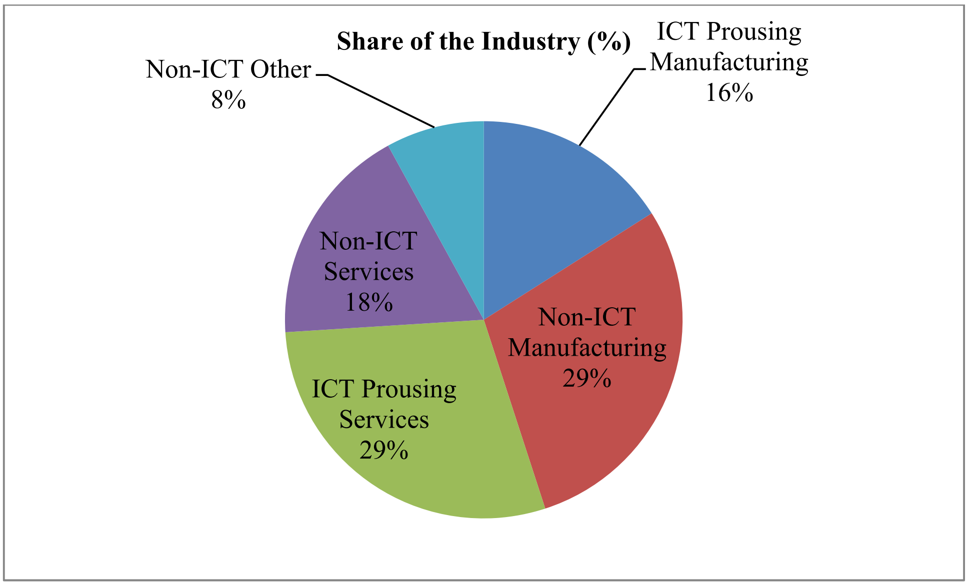


Figure 3.5. Share of Industry (%)
Source:TURKSTAT (2009)

The region dummies which consist of six categories were also added to the regression. These are constructed in terms defined by TURKSTAT (2008a). The first region is Istanbul which is a reference category since 46 percent of the sample comes from this region. Other categories are created based on the guidance of NUTS region category. Table 3.10 shows the distribution of each region into each category.

Table 3.10. Distribution of regions

Region	Frequency	Percent
1	1675	46,11
2	470	12,94
3	450	12,39
4	509	14,01
5	263	7,24
6	266	7,32

Note:1=Istanbul, 2= East and West Marmara Region, 3=Aegean Region, 4=Inner Anatolia, 5=Mediterranean Region, 6=East and South East Anatolia and Black Sea Region
Source:TURKSTAT (2007)

3.5.5. The Problem of Endogeneity

In the literature, the instrumental variable approach is applied to overcome the problem of endogeneity. Basant et al. (2006) used the state and regional average values as an instrument to examine the effect of adoption on firm performance. In other studies, ratio of workers with university or secondary education is used as an instrument (Commander and Svejnar, 2008; Carlin et al. 2006). However, instrumental variable approach has its own shortcomings. Accordingly, valid instruments should satisfy two main conditions such as instrument relevance and and instrument exogeneity (Stock and Watson, 2007).

It is assumed that the population regression model is $Y_i=\beta_0+\beta_1 X_i+u_i$, i=1,…,n, where u_i is the error term including factors that may affect Y_i. When X_i and u_i are correlated, OLS estimator becomes inconsistent. To eliminate this problem, instrumental variable, Z_i, is used to isolate that part of X_i that is uncorrelated with u_i. Instrumental relevance assumes that the variation in the instrumental variable is correlated with the variation in X_i. Instrument exogeneity requires no correlation between the instrumental variable and the error term. In most cases, it is not easy to obtain valid instruments since it requires these strong assumptions.

In this thesis, we examine the effect of firm specific variables on ICT adoption. These variables are firm size, export share, export share square, R&D personnel expenditure, initial software investment, and purposes of ICT usage. While constructing the model, we consider the threat of potential endogeneity between adoption variables and firm specific variables. To mitigate this problem, lagged values of the explanatory variables are used in this study. Therefore, our dependent variables such as technology ownership, the use of ERP and CRM technologies, and the use of narrowband and broadband technologies belong to the 2009 wave of Use of ICT by enterprises survey while the explanatory variables come from the

2007 wave of Structural Business Statistics Survey. Only purposes of ICT usage variables belong to the 2009 wave of Use of ICT by enterprises.

Table 3.11. Definitions of Variables

Dependent Variables	
Technology Ownership	Index variable which is composed of technologies as LAN, WLAN, Intranet and Extranet. Its value ranges between 1 and 4
ERP	Binary variable that takes the value of 1 if the firm uses ERP technology and zero otherwise
CRM	Binary variable that takes the value of 1 if the firm uses CRM technology and zero otherwise
ISDN	Binary variable that takes the value of 1 if the firm uses ISDN technology and zero otherwise
Other Fixed Connection	Binary variable that takes the value of 1 if the firm uses Other Fixed Connection and zero otherwise
Mobile Connection	Binary variable that takes the value of 1 if the firm uses Mobile Connection and zero otherwise
Explonatory Variables	
Human Capital	R&D personnel expenditure per employee (Binary variable that takes the value of 1 if the firm makes R&D personnel expenditure and zero otherwise)
Firm Size	Number of employees(in logarithmic form)
Prior knowledge	Software investment per employee(in logarithmic form)
Foreign Capital	The share of foreign capital (1-100)
Export Share	The share of exports of goods and services in total revenues
Export Share Square	The square of the export share
Purposes of Internet Usage	
E-training	Binary variable that takes the value of 1 if the firm uses internet for the purpose of e-training activities and zero otherwise
E-banking	Binary variable that takes the value of 1 if the firm uses internet for the purpose of e-banking activities and zero otherwise

Table 3.11. Continued

Industry	
ICT Producing Manufacturing	Office machinery(30); Insulated wire(313); Electronic valves and tubes(321);Telecommunication equipment(322); Radio and television receivers(323); Scientific Instruments(331)
ICT Using Manufacturing	Clothing(18); Printing and Publishing(22); Mechanical Engineering(29); Other Electrical Machinery &Apparatus(31-313); Other Instruments(33-331); Building and Repairing of Ships and Boats(351); Aircraft and Spacecraft(353)
ICT Producing Services	Communications(64); Computers and Related Activities(72)
ICT Using Services	Wholesale trade and commission trade(51); Retail trade(52); Financial Intermediation(65); Insurance and pension funding(66); Renting of machinery and equipment(71); Research and development(73); Legal, technical &advertising(741-3)
Non-ICT Manufacturing	Food, drinks, and tobacco(15-16); Textiles(17); Leather and Footwear(19); Wood &Products of Wood and Cork(20); Pulp, Paper and Paper Products(21); Mineral, oil refining, coke& nuclear fuel(23); Chemicals(24); Rubber and Plastics(25); Non-metallic mineral products(26); Basic Materials(27); Fabricated Metal Products(28); Motor Vehicles(34)
Non-ICT Services	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel(50); Hotels and catering(55); Inland transport(60); Water transport(61); Air transport(62); Supporting and auxiliary transport activities; activities of travel agencies(63); Real estate activities(70); Other business activities(749); Public administration and defense; Compulsory social security(75); Education(80); Health and social work(85); Other community, social and personnel services(90-93); Private households with employed persons(95); Extra territorial organizations and bodies(99)
Non-ICT Other	Agriculture(01); Forestry(02); Fishing(05); Mining and quarrying(10-14); Electricity, gas, and water supply(40-41); Construction(45)
Region	
Istanbul	Dummy variable taking the value of 1 if the firm is located in Istanbul and zero otherwise
Rest Marmara	Dummy variable taking the value of 1 if the firm is located in rest Marmara and zero otherwise (Tekirdağ, Edirne, Kırklareli, Balıkesir, Çanakkale, Bursa, Eskişehir ,Bilecik, Kocaeli, Sakarya, Düzce, Bolu, Yalova)
West and Central Anatolia	Dummy variable taking the value of 1 if the firm is located in Inner and Middle Anatolian Regions and zero otherwise (Ankara, Konya, Karaman, Kırıkkale, Aksaray, Niğde, Nevşehir, Kırşehir, Kayseri, Sivas, Yozgat)
Aegean	Dummy variable taking the value of 1 if the firm is located in Aegean Regions and zero otherwise (İzmir, Aydın, Denizli, Muğla, Manisa, Afyonkarahisar, Kütahya, Uşak)
Mediterranean	Dummy variable taking the value of 1 if the firm is located in Mediterranean and zero otherwise (Antalya, Isparta, Burdur, Adana, Mersin, Hatay, K.Maraş, Osmaniye)
Rest Anatolia	Dummy variable taking the value of 1 if the firm is located in Black Sea region, East Anatolia, and South East Anatolia and zero otherwise (Erzurum, Erzincan, Bayburt, Ağrı, Kars, Iğdır, Ardahan, Malatya, Elazığ, Bingol, Tunceli, Van, Muş, Bitlis, Hakkari, Gaziantep, Adıyaman, Kilis, Şanlıurfa, Diyarbakır, Mardin, Batman, Şırnak, Siirt, Zonguldak, Karabük, Bartın, Kastamonu, Çankırı, Sinop, Samsun, Tokat, Çorum, Amasya, Trabzon, Ordu, Giresun, Rize, Artvin, Gümüşhane)

Table 3.12. A list of Variables on ICT Adoption and Expected Signs in the Literature

Variables	Expected Sign	Motivation	Literature
Firm size	+	Scale Economies	Fabiani et al. (2005)
Prior Knowledge	+ -	Acquiring technological knowhow Information asymmetry	Attewell (1992) Shane (2000)
Foreign share	+ n.s.	Access to external network Reduction in risk Not significant	Galliano and Roux (2008);Premkumar and Roberts (1999);Gourlay and Pentecost(2002) Teo and Ranganathan(2004)
Export share	+	Competitive pressure Learning effect	Galliano (2011); Fabiani et al. (2005); Hollenstein (2004); Hall et al. (2003)
Export share square	-	Turns negative effect after a certain point	Hollenstein (2004)
Purpose of ICT Usage	+	Quality improvement, cost reduction, and input improvement Competitiveness	Hollenstein (2004); Arvanitis and Hollenstein (2001); Arvanitis et al. (2002)
Region	+ -	Large effectat the initial stage of adoption Learning Lack of resources in rural area	Baptista (2000);Hagerstrand (1967);Lindner et al. (1982) Martin and Matlay (2001); MacGregor and Vrazalic (2005); Simpson and Docherty (2004)
Industry	+ n.s.	Technical capacity Inter-firm mobility Not significant	Rosenberg (1971); Almeida (1996) Galliaud (2011)

3.5.6. Conclusion

This part deals with the description of the data which is used to analyze the effects of firms specific variables on ICT adoption and diffusion and the effect of software investment on firm efficiency. The data cleaning procedure as well as construction of the variables are elaborated in detail.

As for the adoption and the diffusion part, two different surveys are applied in this thesis. These are "Use of Information and Communication Technology by Enterprises Survey" and "Annual Structural Business Statistics Survey". Both cross section analysis and panel data analysis are conducted by exploiting those data sets. For the cross section analysis, adoption is treated as a decision in one point in time of which a two-year lag between dependent variables and independent variables is introduced. The information on dependent variables are based on the Use of Information and Communication Technology by Enterprise Survey (2009). Independent variables come from the Annual Structural Business Statistics Survey (2007).

The most important point that attracts attention is that from one year to another, the Use of Information and Communication Technology by Enterprises Surveys are subject to several adjustments. Some questions are added to the survey while some are removed. In addition, a set of questions are not included in the survey. To sum up, the main deficits of the survey;

- The question on IT outsourcing activities is only available in the 2007 and 2008 waves of the survey.
- The absence of continuous variables such as hardware and telecommunication expenditure or software investment necessitates merging the dataset with another.

- Lack of clarity in the definition of such concepts as “ownership” or “use”. The difference between technology ownership and use of the technology is not clear in the questionnaire.
- Information on e-commerce activities is not available since most of the data is missing. This implies that the question does not measure e-commerce activities.
- Lack of data on centralization or decentralization in the decision making mechanism.
- Lack of data on managerial ability such as educational level of the manager or manager ‘s skills.

Looking at the common indicators of ICT, the use of computer and internet or the website ownership by the enterprises is quite high in Turkey which does not provide any implication for the effect of ICT as a general purpose technology. In other words, the current version of the ICT questionnaire in Turkey is not adequate to identify if ICT is a general purpose technology which makes changes in the organization of the work. As a general purpose technology, ICT can be elaborated in terms of its relationship with productivity, innovation, outsourcing, and organizational change.

3.6. Estimation Results

This part section discusses the estimation results for the determinants of ICT adoption. ICT adoption is analyzed by applying both cross section data and panel data. For the cross section estimation, dependent variables are generated by using data from the 2009 wave of the Use of Information and Communication Technology by Enterprises Survey. The information on the firm specific factors is based on the 2007 wave of Annual Structural Business Statistics Survey. Two year lags between dependent variables and the explanatory variables are introduced based on the hypothesis that firm specific factors have lagged effects on adoption.

Table 3.13 reports the descriptive statistics of the dependent variables, as well as the correlation matrix for ICT adoption. These variables indicate the level of technological advancement of the firms in the sample. From the data, it can be inferred that differences among ICT indicators are quite remarkable. It is found that 34 percent of the sample is ERP users while 18 percent of the sample uses CRM. On the other hand, the use of ISDN which represents narrowband technology is 20 percent indicating that firms in the sample can be referred to as “advanced technology users”. Based on the correlation matrix, it can be observed that the correlations between different ICT indicators are quite high. In fact, only ISDN shows a weak relationship. The highest correlations are observed among the variables, technology ownership, other fixed connections, and mobile connections.

Table 3.14 reports the descriptive statistics of the explanatory variables. A great proportion of the firms in the sample use e-banking applications while 43 percent in the sample use internet for e-training applications. It can be inferred that the use of ICT for the multiple purposes including e-training and e-banking is not at the desired level. As for the other explanatory variables, 10 percent of the sample sells their products on the international markets while the share of firms with R&D personnel expenditure is low.

As for the panel data estimation of the ICT adoption, Annual Structural Business Statistics Survey (2003-2007) is merged with the Use of Information and Communication Technology by Enterprises Survey (2007-2011). In this part of the chapter, a four year lag between dependent variables and independent variables is introduced to test whether or not firm specific factors generate similar effects as the time span is extended.

3.6.1. Cross Section Estimation Results for Technology Ownership

Technology ownership index which is determined at four levels is estimated by using the ordered logit model. Accordingly, moving from 1 to 2 or 1 to 3 indicates the technological advancement of the firm (see Appendix 1 and 2 for the multinomial estimation results). 28 percent of the sample consists of firms having a single technology while 36 percent of the firms have two technologies. The share of firms having three technologies is about 21 percent. Finally, firms having four technologies constitutes 17 percent of the sample. Hence, firms are almost evenly distributed through each category.

Table 3.15 displays the estimation results for the technology ownership model. The first column belongs to the full model. The remaining columns show the marginal effects for each technology level. In model 1, the dependent variable reflects "one technology using firm" In model 2, two technology-using firms are evaluated. Similarly for model three and model four.

Rank effects are represented by firm size, competitiveness, initial software investment, foreign share, and human capital while region and industry dummies constitute the epidemic effects.

3.6.1.1. Overall Estimation of Technology Ownership

The first column of Table 3.15 displays the overall estimation results for the technology ownership. According to this, almost all of the explanatory variables have positive and significant effect on technology ownership.

Firm size is measured as the logarithm of the average number of employees. In this thesis, 26 percent of the sample is composed of small firms, 35 percent of the sample is small and medium sized enterprises, and 40 percent of the sample consists of large firms. Hence, firms in the sample have almost equal proportion. Looking at the ICT investment by size, large firms invest in ICT more than others. A one unit increase in firm size generates 0.41 unit increase in the ordered log-odds of being in a higher category of technology ownership[32].

Export share also enter into the equation assuming that technology ownership increases with openness to trade but at a decreasing rate. After a certain threshold, exporting is not a relevant activity for technology adopters. Thus, the square term of export share has a negative effect which amounts to a 2.8 point reduction in the technology ownership index[33].

Underestimating the role of intangible assets such as investment in software in the adoption process generates omitted variable bias. In this thesis, an initial investment in software is used in order to reveal its role in building up the ICT infrastructure. Software investments in 2007 are used to proxy the initial software investment. This variable is generated by dividing software investment into firm turnover and it is in logarithmic form. Initial software investment is positively associated with technology ownership and it generates a 0.13 point increase in technology ownership.

As for foreign ownership, 9 percent of the firms in the sample are owned by foreign firms. The share of foreign firms ranges from 0 to 100. 91 percent of the sample takes the value of zero. Although the number of firms having

[32] Looking at the effect of firm size in each category, there is not much difference between the categories. For instance, for firms having single technology the mean of firm size is about 4.57 while it increases to 5.83 for firms having four technologies. Yet, the difference between firms having three technologies and four technologies is significant in terms of firm size (*chisquare=3.7e+03, Pr=0.000)*.

[33] Firm size differs in terms of export share and this difference is significant. According to this, 50 percent of the firms which do export is composed of large firms and it is significant (*chisquare=131.2840*).

foreign shares is small, its effect is positively significant and generates a 0.001 point increase in the technology ownership index[34].

Human capital is another rank variable drawing attention into the absorptive capacity of the firm. It is measured in different ways. The share of white collar workers, wage per employees, user training, and the educational levels of the workers are just a few examples of human capital measures. In this thesis, the costs of R&D employees are used to analyze its effect on technology ownership. Based on the assumption that the amount the firm invests in human capital, the faster the adoption hence, this variable is formed by taking the logarithm of R&D personnel costs. For one unit increase in R&D personal costs results in a 3.76 increase in the probability of having a higher level of technology ownership.

Purposes of internet usage are e-banking and e-training activities both of which have positive and significant effects on technology ownership. Specifically, the use of the internet for the purpose of e-banking and e-training generates a 0.65 unit increase in the ordered log-odds of being in a higher category of technology ownership.

As for the industry dummies, coefficients of Non ICT Other, Non ICT Manufacturing, and region dummies have negative effects on technology ownership. These negative effects are clearly observed in agriculture sectors and construction sectors, which are grouped under the Non ICT other, due to the applications of low level of technology. Nonetheless, in Non ICT Services where low technology is applied, the coefficient is 0.342 and in Non ICT Producing Services, the coefficient is 0.184. These estimation results clearly indicate that the application of low technology does not always correspond with low coefficients. When looking at the composition

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[34] Foreign share is at the highest level for large firms and difference between firms with regard to foreign ownership is significant *(chisquare=127.8759).*

of the industry, 30 percent of the Non ICT service producers are in the segment of hotels and restaurants by which the internet applications such as "online reservation" or "order online facilities" are in common use.

Region dummies used in this thesis consists of 6 categories. The reference category is Istanbul where most of the firms in the sample are concentrated. The remaining regions have negative effects on technology ownership which indicates that operating in regions other than Istanbul is disadvantageous for firms.

Coefficients of the Mediterranean and Rest Anatolia are larger than the others which are composed of unfavored cities in terms of availability of ICT infrastructure. These regions include cities in the Mediterranean Region, theBlack Sea Region, and the Eastern and Southeastern Anatolian Regions.

3.6.1.2. Comparison of different levels of technology ownership

Based on the estimation results for firms with a single technology, firm size has a negative effect on technology ownership. Therefore, one unit increase in firm size results in a 0.07 point decrease in the probability of having the single type of technology is introduced. In addition, the effect of size on technology ownership in Model 2 is negative and significant. The value turns into positive for Model 3 and Model 4. This result is consistent with the assumption that the larger the firm size, the higher technology usage is (Fabiani et al., 2005; Baldwin et al., 2004; Delone, 1981; Morgan et al., 2006; Teo and Tan, 1998; Morionez and Lopez, 2007).

The negative effect of export share is greater than those of the firm size. According to this, a 0.33 percent decrease in the probability of a single type technology ownership is associated with a 1 unit increase in export share. Similarly for Model 2, the negative effect of export share contrasts with some of the previous literature which associates a positive link for the adoption of single technologies such as internet and e-selling (Hollenstein, 2004). On the other hand, there is a threshold level of technology ownership, at which point the effect of export share becomes positive. For models 3 and 4, it provides positive and significant effects. Therefore, access to external networks through exporting activities generates benefits for firms which use the three or four technologies. In addition, exporting firms have the knowledge of more recent technologies which motivate them to adopt multiple complementary technologies.

A similar situation is observed in the case of initial investment. Signs of the initial software investment are positive in the full model and negative in the case of one and two technology ownership models, turning positive in the 3 and 4 technology ownership models. Again there is a threshold level of technology ownership at which the initial software investment turns positive. These results imply that when one or two technologies are used, large software investment may not be needed. However, when three or four technologies are used, a large initial software investment is necessary.

Another explanatory variable, e-banking, refers to the firm's online banking activities. The effect of e-banking on the probability of technology ownership is positive in the full model. The effects are negative in the one and two technology ownership models, but positive in the three and four technology ownership models. A similar pattern is observed with respect to e-training. These results indicate that the use of e-banking and e-training activities requires ownership of more than two technologies.

Considering the effect of human capital, in the full model, R&D personnel expenditure per employee increases the probability of technology ownership with a large coefficient estimate. This coefficient estimate is negative in the one and two technology ownership models, but turns positive in the 3 and 4 technology ownership models. These results imply that R&D personnel expenditure per employee reduces the probability of one and two technology ownership but increases the probability of three and four technology ownership. Again indicating a threshold level of technology ownership, we next discuss the effect of various sectors on the probability of technology ownership.

The base sector is ICT producing and using in manufacturing. The ICT producing and using services sector has a positive impact on the probability of technology ownership. In the full model, it is negative, and significant in the one technology model, but insignificant in the two technology ownership model. It is positive and significant in the three and four technology ownership models, where similar patterns are observed in the case of the non ICT services sector. Coefficient estimates are insignificant in the non ICT manufacturing sector and non ICT other sector cases.

For the services sector, regardless of producing, using or not using ICT, the effects on the probability of technology ownership are significant. However, the effects of non ICT manufacturing and non ICT other on the probability of technology ownership are insignificant.

The effects of various regions are negative and significant to the probability of three and four technology ownership models, while the rest is insignificant. These results indicate that various geographical regions increase the probability of one and two technology ownership relative to Istanbul, while several regions reduce the probability of three and four technology ownership.

Table 3.13. Descriptive Statistics and Correlations for Dependent Variables

Dependent Variables	Mean	Std. Dev.	Technology Ownership	ERP	CRM	ISDN	Other Fixed Connection	Mobile Connection
Technology Ownership	2.25	1.03						
ERP	0.34	0.47	0.40**					
CRM	0.18	0.38	0.30**	0.34**				
ISDN	0.20	0.4	0.08**	-0.002	0.03			
Other Fixed Connection	0.34	0.47	0.44**	0.35**	0.25**	0.10**		
Mobile Connection	0.3	0.46	0.44**	0.30**	0.24**	0.12**	0.42**	

** $p < 0.05$

Table 3.14. Descriptive Statistics and Correlations for Independent Variables

Independent Variables	Mean	Std. Dev.	Firm Size	Export Share	Export Share^2	Foreign Share	E-Banking	E-Training	R&D	Software
Firm Size	5.08	1.31								
Export Share	0.1	0.19	0.22**							
Export Share^2	0.04	0.11	0.18**	0.96**						
Foreign Share	6.16	22.32	0.15	0.13	0.12					
E-Banking	0.87	0.33	0.10	0.08	0.06	0.07				
E-Training	0.43	0.49	0.10	0.04	0.03	0.09	0.17**			
R&D	0.007	0.04	0 .02	0 .02	0 .009	0 .06	0 .04	0.09		
Software	1.03	2.09	0.20**	0.13	0.09	0.18	0.12	0.10	0.05	

Note:R&D represents R&D personnel expenditure per employee, Software represents initial software investment per employee
$**p<0.05$

Table 3.15. Estimation Results for Technology Ownership

Variables	Tech.Ownership	Model1	Model2	Model3	Model4
Firm Size	0.410***	-0.074***	-0.019***	0.050***	0.042***
	(0.03)	(0.00)	(0.00)	(0.00)	(0.00)
Export Share	1.851***	-0.332***	-0.086***	0.227***	0.191***
	(0.61)	(0.11)	(0.03)	(0.08)	(0.06)
Export Share Square	-2.80***	0.502***	0.129***	-0.343***	-0.289***
	(1.02)	(0.18)	(0.05)	(0.13)	(0.11)
Software	0.128***	-0.0230***	-0.00593***	0.0157***	0.0132***
	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)
Foreign Share	0.00959***	-0.00172***	-0.000443***	0.00117***	0.000988***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R&D	3.759***	-0.674***	-0.174***	0.460***	0.387***
	(0.91)	(0.16)	(0.05)	(0.11)	(0.09)
E-Banking	0.647***	-0.130***	-0,00297	0.0775***	0.0556***
	(0.10)	(0.02)	(0.01)	(0.01)	(0.01)
E-Training	0.650***	-0.114***	-0.0342***	0.0779***	0.0699***
	(0.06)	(0.01)	(0.01)	(0.01)	(0.01)
ICT Producing, Using Services	0.184*	-0.0323*	-0,00965	0.0224*	0.0195*
	(0.10)	(0.02)	(0.01)	(0.01)	(0.01)
Non ICT Services	0.342***	-0.0578***	-0.0216**	0.0411***	0.0383***
	(0.11)	(0.02)	(0.01)	(0.01)	(0.01)
Non ICT Other	-0,0194	0,0035	0,000871	-0,00238	-0,00199
	(0.14)	(0.02)	(0.01)	(0.02)	(0.01)
Non ICT Manufacturing	-0,0371	0,00667	0,00166	-0,00454	-0,0038
	(0.09)	(0.02)	(0.00)	(0.01)	(0.01)
Rest Marmara	-0,0295	0,00532	0,00131	-0,00362	-0,00302
	(0.10)	(0.02)	(0.00)	(0.01)	(0.01)
Aegean	-0.220**	0.0411**	0.00707***	-0.0269**	-0.0212**
	(0.10)	(0.02)	(0.00)	(0.01)	(0.01)
West and Central Anatolia	-0.352***	0.0674***	0.00865***	-0.0430***	-0.0330***
	(0.10)	(0.02)	(0.00)	(0.01)	(0.01)
Mediterranean	-0.635***	0.129***	-0,000305	-0.0758***	-0.0532***
	(0.13)	(0.03)	(0.01)	(0.01)	(0.01)
Rest Anatolia	-0.766***	0.159***	-0,0075	-0.0901***	-0.0616***
	(0.14)	(0.03)	(0.01)	(0.02)	(0.01)
Cut 1 Constant	1.945***	**Cut 2 Constant**	5.155***	**Cut 3 Constant**	5.155***
	(0.17)		(0.18)		(0.19)
McFadden's R2	0,10	0,13	0,019	0,051	0,14
Loglikelihood	-4384,181	-1861,465	-2321,744	-1779,176	-1347,757
Observations	3,633	3,633	3,633	3,633	3,633

*** p<0.01, ** p<0.05, * p<0.10, Robust standard errors in parentheses

Figure 3.6 displays the predicted probabilities for each outcome according to the changing values of R&D personnel expenditure. Its value varies from 0 to 1. Accordingly, the probability of having a single technology, pr(1), decreases with the R&D personnel expenditure. While the probability of having two technologies, pr(2), increases with R&D personnel expenditure at the beginning, it decreases after a certain point. It is similar for the probability of having three technologies, pr(3). On the other hand, the threshold point is higher in the case of three technologies. As far as the cumulative probabilites are concerned, only the probability of having four technologies, pr(4), increases gradually.

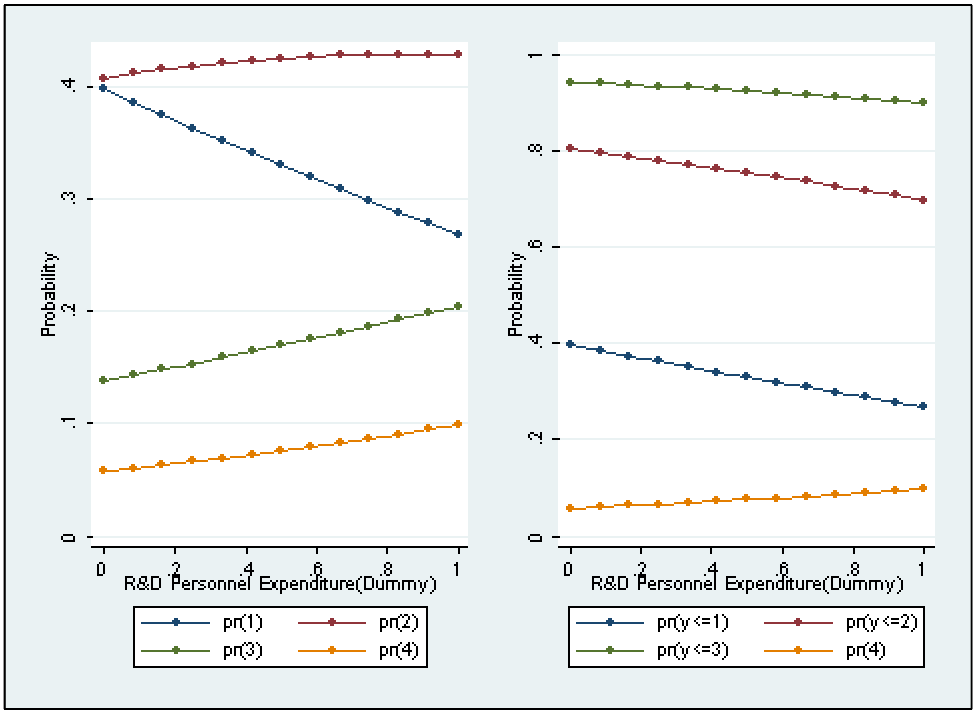


Figure 3.6. Predicted and Cumulative Probabilities of R&D Personnel Expenditure

Figure 3.7 displays the effect of firm size on the predicted probability of each of technology level. Therefore, in this scenario, firms do not export and do not use the internet for e-banking activities. The predicted probability of having four technologies increases with firm size. For firms having three technologies, the predicted probability starts decreasing after a certain point. The predicted probability of having two technologies begins to decline earlier.

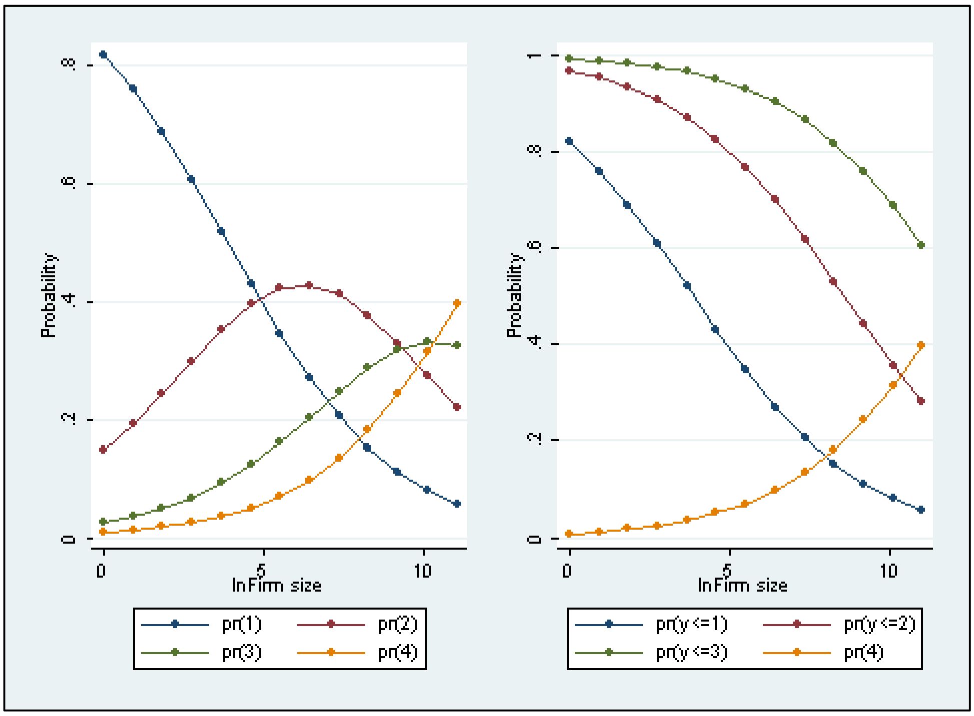


Figure 3.7. Predicted and Cumulative Probabilities of Firm size (E-Banking=0 & Export share=0)

According to the alternative scenario, firms use e-banking activities and do have a specific level of exporting activities[35]. The value of this variable ranges from 0 to 0.83. Hence, the rate of increase in predicted probability is steeper for firms having four technologies (see, Figure 3.8). Suprisingly, the predicted probability of having two and three technologies decreases earlier in comparison to the first situation of which there is no banking and exporting activity. It shows that firm size is closely associated with the advanced level of technology ownership. However, only selected independent variables are included, therefore, the effects of other variables are underestimated in these cases.

[35] Exporting activities are measured by the share of exports of products and services to total sales.

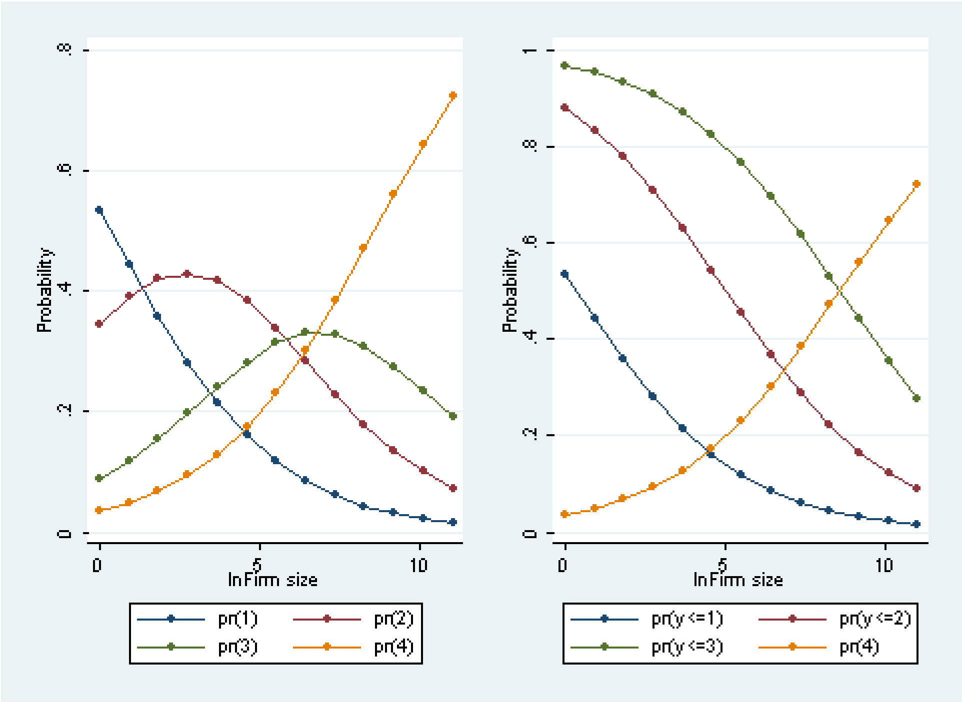


Figure 3.8. Predicted and Cumulative Probabilities of Firm size (E-banking=1 & Export Share=0.50)

Figure 3.9 shows the case of firms using e-banking activity and do not make software investment per employee. Export share increases with the predicted probability of having four technologies. Yet, for firms having three technologies, it decreases after some point.

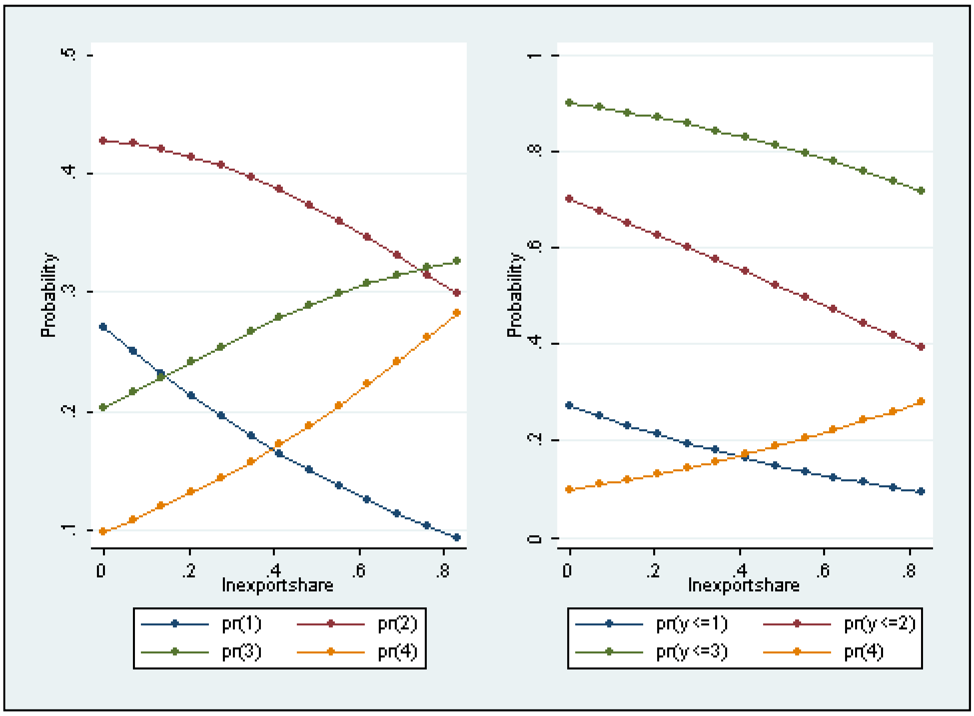


Figure 3.9. Predicted and Cumulative Probabilities of Export Share (E-Banking Activity=1 & Software investment per Employee=0)

In the second situation of firms do which e-banking activity and make software investment per employee, the predicted probability of having three-technology increases at the beginning but decreases after a certain point (see Figure 3.10). The threshold value is about 0.75 which means firms using three technologies do not export after that point.

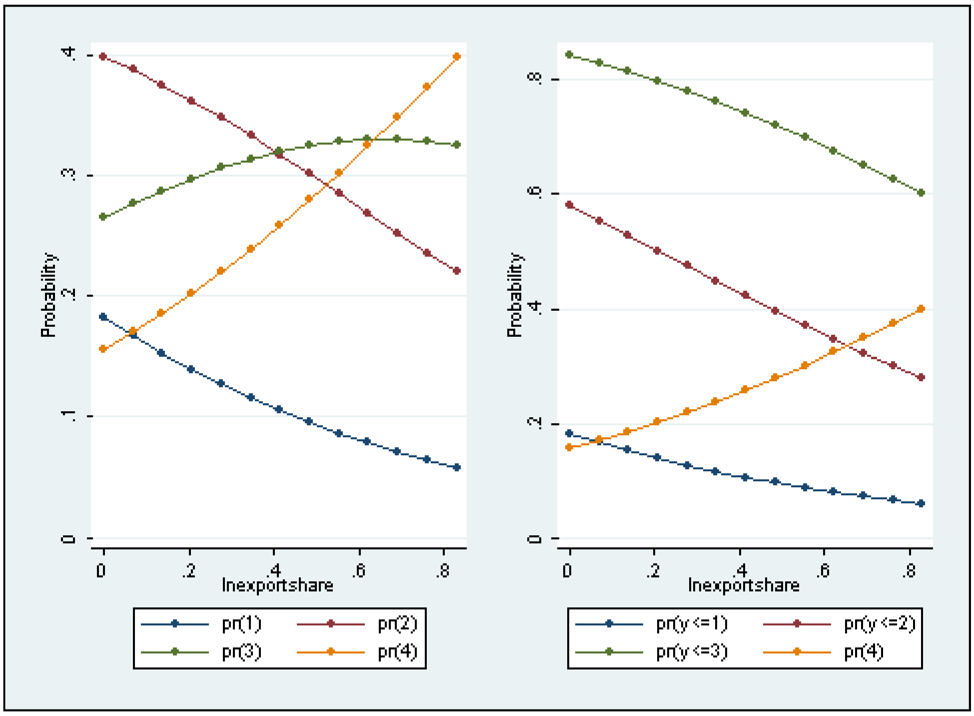
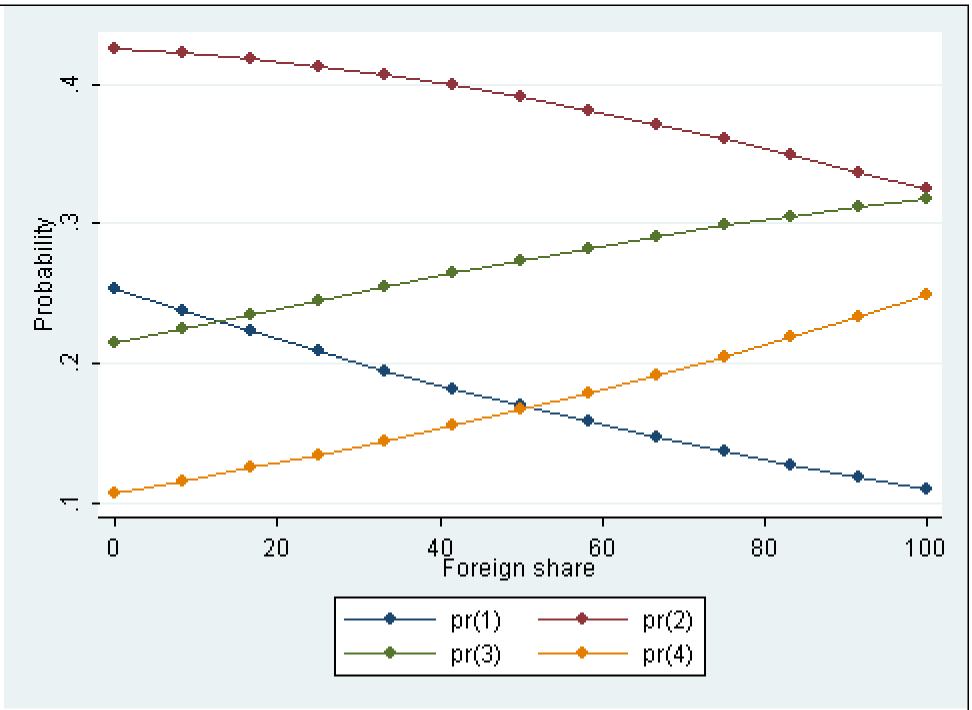


Figure 3.10. Predicted and Cumulative Probabilities of Export Share (E-Banking Activity=1 & ICT investment per Employee>0)

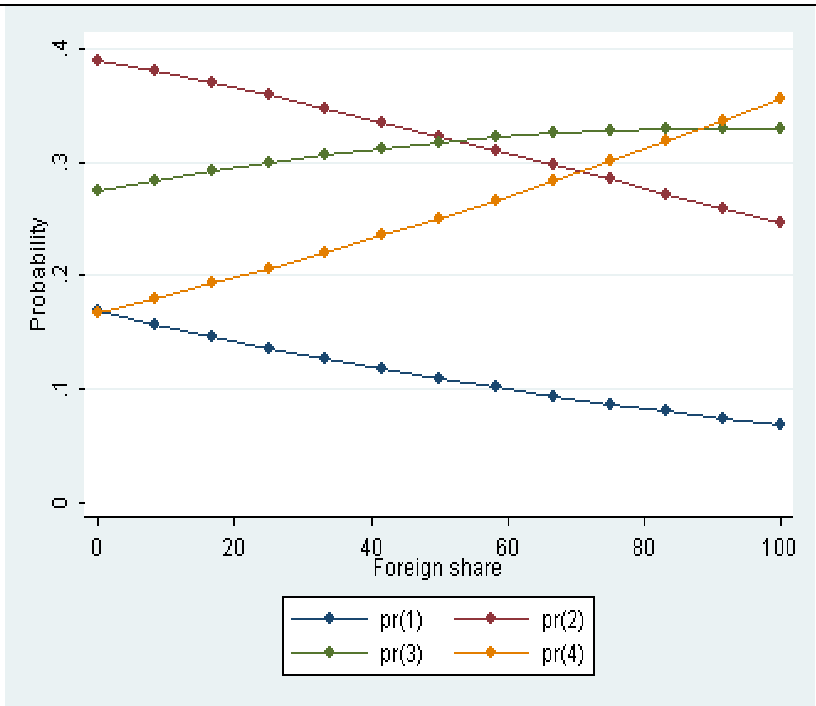
Looking at the predicted probabilities of each outcome for the variable foreign share, the probability of having three and four technologies increases with foreign shares while this is not the case for firms having single technology or two technologies (see Figure 3.11).



Pr(1)	0.25	0.22	0.18	0.16	0.11
Pr(2)	0.43	0.42	0.40	0.38	0.32
Pr(3)	0.21	0.24	0.26	0.28	0.32
Pr(4)	0.11	0.13	0.15	0.18	0.25

Figure 3.11. Predicted Probabilities of Foreign Share (E-Banking Activity=1 & ICT investment per Employee=1)

However, in Figure 3.12, where firm size takes the highest value (max=10.55), the predicted probability of having three technologies for large firms decreases with foreign share while the starting point of predicted probability is much higher for large firms having four technologies. This implies that firm size is fairly decisive in having foreign share for firms having four technologies.



Pr(1)	0,17	0,14	0,12	0,10	0,08
Pr(2)	0,39	0,37	0,34	0,31	0,28
Pr(3)	0,27	0,29	0,31	0,33	0,33
Pr(4)	0,17	0,20	0,23	0,31	0,36

Figure 3.12. Predicted Probabilities of Foreign Share (E-Banking Activity=1 & ICT investment per Employee=0)

3.6.2. Cross Section Estimation Results for ERP, and CRM

Enterprise resource planning systems provide integration of business management processes across different business functions (Mabert et. al.,2000). Size matters in the adoption of this technology since implementation costs are higher. Even if small firms could bear these costs, they focus on software investment while large firms are much more concerned with the organization of the ERP teams (Mabert et al., 2003). In this thesis, observations are based on the implementation stage of the technology. Hence estimation results show the usage of the system rather than the investment. On the other hand, it does not reflect the factors which motivate firms to invest in this technology.

Firm size does not exhibit a large positive effect on customer resource management owners as in the case of enterprise resource planning applications. The effect of export share is positive and having CRM application increases the probability of exporting by 0.30 percent. In addition, firms having foreign capital are better able to use this system despite its small share. Research and development expenditure per employee has a positive effect on the probability of having CRM. While the use of CRM is observed less in the manufacturing industry, its effect is positive and significant. CRM applications are more common in the services industry. As to the region dummies, only the Aegean, Western, and Central Anatolia give significant results which are negative for the CRM owners in these regions. It shows that CRM is not a relevant application in terms of the firm's activities.

In Table 3.16, the effect of firm size is larger in comparison to the model in which the customer resource management is modeled. The effect of firm size on using the enterprise resource planning system is about 10 %. Coming to the openness to trade which is measured as the share of exports in total sales of the firm, there is a positive association between ERP and export share. It has been found that the performance of non-adopters deteriorates in a competitive marketplace. Attracting foreign direct investment is crucial for adopting ERP systems. Even in the case of high investment intensity in infrastructure, there are some environmental or governmental factors encouraging foreign direct investment. The survey period in this thesis corresponds with the privatization of the sector which is expected to trigger competition on the market. Therefore, the positive effect of foreign share may be due to the reforms towards liberalization.

3.6.3. Cross Section Estimation Results for Connection Types

Table 3.17 demonstrates the estimation results for narrowband technologies and broadband technologies. For narrowband technologies which show the use of ISDN, almost all variables give insignificant results and a weak model fit value (*McFadden's R2=0.01*). Coming to the estimation results for broadband connections, for other fixed connection, firm size gives larger and significant effects in comparison to results for narrowband technology use. Firm size is also significant for mobile connection as GPRS but its effect is smaller than the other fixed connection. This result implies that large firms are more inclined to use other fixed connection because it provides a faster connection than the mobile connection. The effect of foreign share is larger in both other fixed connection and mobile connection. E-banking activities have significant and negative effect on narrowband technology which is consistent with the assumption that e-banking activities require certain levels of technological competence and experience which do not exist in narrowband technologies.

Table 3.16. Estimation Results for ERP and CRM

VARIABLES	ERP	CRM
Firm size	0.102***	0.0323***
	(0.00692)	(0.00483)
Export share	0.723***	0.304**
	(0.163)	(0.122)
Export share square	-1.010***	-0.513**
	(0.274)	(0.203)
Software	0.0302***	0.0107***
	(0.00393)	(0.00284)
Foreign share	0.00252***	0.000883***
	(0.000411)	(0.000248)
R&D	0.556***	0.471***
	(0.209)	(0.130)
E-banking	0.130***	0.0595***
	(0.0241)	(0.0179)
E-training	0.133***	0.107***
	(0.0171)	(0.0129)
ICT ProUsing_Services	-0,0399	0.0737***
	(0.0258)	(0.0226)
Non ICT Services	-0.0477*	0.121***
	(0.0276)	(0.0270)
Non ICT Other	-0.155***	-0.0645***
	(0.0289)	(0.0240)
Non ICT Manufacturing	0,0208	-0,0261
	(0.0249)	(0.0191)
Rest Marmara	0.130***	-0,0261
	(0.0280)	(0.0179)
Aegean	-0.0818***	-0.0720***
	(0.0237)	(0.0156)
West and Central Anatolia	-0.0555**	-0.0392**
	(0.0247)	(0.0170)
Mediterranean	-0.109***	0,0120
	(0.0300)	(0.0249)
Rest Anatolia	-0.0749**	0,0132
	(0.0329)	(0.0262)
McFadden's R2	0.20	0.10
Loglikelihood	-1861,465	-4384,181
Observations	3633	3633

*** $p<0.01$, ** $p<0.05$, * $p<0.1$, Robust standard errors in parentheses

Note: See Appendix 6 and 7 for the further estimations

Table 3.17. Estimation Results for Connection Types

VARIABLES	ISDN	Other Fixed Connection	Mobile Connection
Firm size	0,00538	0.124***	0.0645***
	(0.00534)	(0.00710)	(0.00627)
Export share	0,207	0.669***	0.566***
	(0.135)	(0.167)	(0.156)
Export share square	-0,287	-0.873***	-0.724***
	(0.224)	(0.278)	(0.259)
Software	-0,00407	0.0178***	0.0206***
	(0.00332)	(0.00403)	(0.00364)
Foreign share	0.000690**	0.00326***	0.00209***
	(0.000292)	(0.000411)	(0.000351)
R&D	-0,00676	0.0221**	0,00615
	(0.00721)	(0.00884)	(0.00729)
ICT_ProUsing_Services	0,0218	0.0916***	0.157***
	(0.0218)	(0.0289)	(0.0283)
Non ICT Services	-0,0107	0.156***	0.111***
	(0.0228)	(0.0324)	(0.0313)
Non ICT Other	0,00860	-0,0209	0.0653*
	(0.0302)	(0.0381)	(0.0393)
Non ICT Manufacturing	-0.0450**	0,00596	0.0486*
	(0.0197)	(0.0265)	(0.0257)
E-banking	-0.0368*	0.129***	0.127***
	(0.0222)	(0.0248)	(0.0225)
E-training	0.0329**	0.133***	0.164***
	(0.0139)	(0.0171)	(0.0159)
Rest Marmara	-0,0281	-0.0571**	-0.0778***
	(0.0201)	(0.0242)	(0.0215)
Aegean	0,0224	-0.103***	-0.0586***
	(0.0219)	(0.0237)	(0.0224)
West and Central Anatolia	-0.0358*	-0.0529**	-0.108***
	(0.0192)	(0.0240)	(0.0203)
Mediterranean	-0.0413*	-0.174***	-0.148***
	(0.0244)	(0.0255)	(0.0228)
Rest Anatolia	-0,0197	-0.148***	-0.139***
	(0.0258)	(0.0274)	(0.0252)
McFadden's R2	0.01	0.14	0.20
Loglikelihood	-1793.792	-1887.527	1857.015
Observations	3633	3633	3633

*** p<0.01, ** p<0.05, * p<0.1 Robust standard errors in parentheses

Note: See Appendix 8-10 for the further estimations.

3.6.4. Panel Data Estimation Results for Technology Ownership

In this section, three different panel data methodologies are used to estimate technology ownership. These are panel data first differencing, bucologit fixed effect estimator, and Ferrer-i Carbonell and Frijters (2004) fixed effect estimators.

Panel data first differencing methodology is applied to estimate marginal effects for each category in the technology ownership index. Marginal effects are calculated by using predicted values of each outcome. Since there is no panel data specification of ordered logit model, predicted outcomes are calculated by ordinary least squares.

As far as the alternative fixed effects estimators are considered, bucologit and Ferrer-i Carbonell and Firijters (2004) estimators are applied in this section in order to check the robustness of panel data first differencing.

3.6.4.1. Panel Data First Differencing

Table 3.18 exhibits the overall estimation results for panel data first differencing which is estimated by GLLAMM[36]. As mentioned in section 3.4.1.2, the procedure which is proposed by Hove et al. (2011) is followed to obtain fixed and random effect estimation of technology ownership. According to the overall estimation results, firm size, software investment, foreign share, e-banking and e-training activities have positive and significant effect on the panel estimation of technology ownership. Only the coefficients of export share and export share square do not give significant results.

[36] This procedure is proposed by Hove et al. (2011). Accordingly, GLLAMM procedure is run by setting function of binomial distribution and adapt option. Binomial distribution indicates the discrete probability distribution which is calculated for the success of n independent yes/no experiment.

Table 3.18. Panel Data First Differencing Overall Estimation Results

VARIABLES	Technology Ownership
Firm size	0.352***
	(0.0568)
Export share	0.0841
	(0.651)
Export share square	-0.0424
	(0.849)
Software	0.134***
	(0.0227)
R&D	0.0881***
	(-0.0199)
Foreign share	0.00350**
	(-0.00165)
E-banking	0.930***
	(-0.236)
E-training	0.644***
	(-0.108)
Regional Agglomeration	-0.759
	(-0.938)
Cut1 Constant	1.606***
	(-0.448)
Cut 2 Constant	3.101***
	(-0.452)
Cut 3 Constant	4.541***
	(-0.461)
Year 1 Constant	0.265**
	(-0.109)
Observations	1610

*** p<0.01, ** p<0.05, *p<0.1,
Robust standard errors in parentheses

After obtaining overall estimation results for technology ownership, the predicted probabilities for each outcome are calculated. As a result, marginal effects of each outcome are calculated by using predicted values (see, Table 3.19). Accordingly, the effects of firm size are negative and significant in technology models one, two, and three. Only in model four, does its effect turns out to be positive and significant. This indicates that in the long run, being a large firm plays a more crucial role in the adoption of complementary technologies. Surprisingly, openness which is proxied by export share gives positive and significant result for one technology and four-technology models. As for the effect of export share square, there is a threshold level of technology ownership, at which point the effect of export share becomes negative. To illustrate, after predicting the single technology model, the effects of export share become positive for two and three technology models. It turns out to be negative for the four technology model.

For the effect of software investment on technology ownership, its effect is positive only for the four technology models. The same is true for research and development expenditure per employee and foreign share.

Regional agglomeration does not have significant effect in any of the models. As for the e-banking activities and e-training activities, their effects are negative in the one and two technology ownership models, but positive in the three and four technology ownership models.

Table 3.19. Marginal effects for the first differenced panel effects

VARIABLES	(re)	(fe)	(re)	(fe)	(re)	(fe)	(re)	(fe)
	One technology		Two technology		Three technology		Four technology	
Firm size	-0.0277***	-0.0282***	-0.0344***	-0.0344***	-0.0118***	-0.0109***	0.0739***	0.0735***
	(0,000718)	(0,000914)	(0,000429)	(0,000545)	(0,00111)	(0,00142)	(0,000526)	(0,000697)
Export share	0.0149*	0.0201**	-0.0117**	-0,00762	-0.0233*	-0.0330**	0.0200***	0.0205***
	(0,00834)	(-0,01)	(0,00499)	(0,00597)	(0,013)	(0,0155)	(0,00616)	(0,00765)
Export share square	-0.0248**	-0.0346***	0,00841	0,00296	0.0313*	0.0488**	-0.0145*	-0.0172*
	(0,0108)	(0,0128)	(0,00644)	(0,00762)	(0,0167)	(0,0198)	(0,00798)	(0,00975)
Software	-0.00901***	-0.00911***	-0.0140***	-0.0140***	-0.00673***	-0.00660***	0.0298***	0.0297***
	(0,00027)	(0,000312)	(0,000161)	(0,000186)	(0,000419)	(0,000483)	(0,0002)	(0,000238)
R&D	-0.00614***	-0.00638***	-0.00889***	-0.00895***	-0.00421***	-0.00380***	0.0192***	0.0191***
	(0,000254)	(0,000314)	(0,000152)	(0,000187)	(0,000394)	(0,000486)	(0,000187)	(0,000239)
Foreign share	-0.000190***	-0.000192***	-0.000350***	-0.000357***	-0.000238***	-0.000238***	0.000777***	0.000787***
	(2.18E-05)	(2.84E-05)	(1.30E-05)	(1.69E-05)	(3.38E-05)	(4.41E-05)	(1.59E-05)	(2.17E-05)
Regional Agglomeration	-0,004	-0,00963	0.0118*	0,0102	0,00171	0,00914	-0,00951	-0,00974
	(0,0117)	(0,0131)	(0,00696)	(0,00783)	(0,0181)	(0,0204)	(0,00869)	(0,01)
E-banking	-0.139***	-0.137***	-0.0734***	-0.0747***	0.0660***	0.0647***	0.146***	0.147***
	(0,00291)	(0,00331)	(0,00174)	(0,00197)	(0,00451)	(0,00513)	(0,00216)	(0,00253)
E-training	-0.0535***	-0.0538***	-0.0702***	-0.0705***	-0.0144***	-0.0141***	0.138***	0.138***
	(0,00137)	(0,00152)	(0,000815)	(0,000908)	(0,00212)	(0,00236)	(0,00102)	(0,00116)
Constant	3.26E-05	1.78E-05	-1.53E-05	-9.88E-06	-5.09E-05	-3.00E-05	3.01E-05	2.20E-05
	(0,00114)	(0,000819)	(0,00069)	(0,000488)	(0,00178)	(0,00127)	(0,000791)	(0,000625)
R-squared		0,871		0,963		0,379		0,985
Number of id	322	322	322	322	322	322	322	322
Observations	1610	1610	1610	1610	1610	1610	1610	1610

*** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses
Note: Modified Wald test for groupwise heteroskedasticity in fixed effect
regression model confirms the presence of heteroscedasticity of the each model

3.6.4.2. Alternative Fixed Effect Estimators

In order to obtain consistent estimation of the fixed effects, a set of alternative fixed effect estimators are generated in the literature[37]. Two of which are Bucologit fixed effect estimator and Ferrer-i Carbonell and Frijters (2004) estimators are used. Based on the results, only firm size and e-training activities give positive and significant results in the fixed effects (see, Table 3.20).

Table 3.20. Alternative Fixed Effect Estimators

VARIABLES	**Bucologit Fixed Effect Estimator**		**Ferrer-i Carbonell and Frijters(2004) Fixed Effect Estimator**	
Firm size	0.366**	0.364**	0.468*	0.491*
	(0.186)	(0.186)	(0.245)	(0.259)
Export share	0.135	0.186	0.175	0.253
	(1.349)	(1.345)	(1.69)	(1.771)
Export share square	-0.342	-0.391	-0.438	-0.529
	(1.718)	(1.711)	(2.16)	(2.263)
Software	0.0299	0.0316	0.0376	0.0419
	(0.0383)	(0.0384)	(0.0481)	(0.0508)
R&D	0.0578	0.0566	0.0725	0.0746
	(0.0534)	(0.0537)	(0.0672)	(0.0712)
Foreign share	0.0071	0.00706	0.00896	0.00938
	(0.00838)	(0.00837)	(0.0105)	(0.011)
E-banking	0.194	0.205	0.246	0.274
	(0.452)	(0.454)	(0.57)	(0.601)
E-training	0.350**	0.352**	0.439**	0.465**
	0.167	0.167	0.21	0.221
Regional Agglomeration		-0.888		-1.17
		0.819		1.083
Observations	1610	1610	1610	1610

*** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses

[37] These are elaborated in detail in Chapter 3.

3.6.4.3. Panel Data Estimation Results for ERP and CRM Technologies

Panel data estimation is also conducted for the ERP and CRM technologies. For the ERP technologies, the fixed effect does not give significant result while most of the variables are significant in the random effect model (see Table 3.21).

Table 3.22 demonstrates the estimation results in manufacturing sectors and services sectors. Accordingly, firm size provides positive and significant effects for the use of ERP in the manufacturing sector while its effects on the use of CRM are negative and significant. In addition, foreign shares have positive and significant effects on the use of CRM in the manufacturing sector.

Table 3.21. Panel Data Estimation Results for ERP

VARIABLES	(fixed effect)	(random effect)
Firm size	0.405	0.422**
	0.292	(0.171)
Export Share	-0.466	1.389
	2.125	(1.74)
Export Share Square	1.758	1.021
	2.575	(2.117)
Initial Software Investment per Emp.	0.0174	0.155***
	0.0607	(0.0531)
R&D	0.0822	0.171***
	0.103	(0.0639)
Foreign share	0.0476	0.0124**
	0.0398	(0.00624)
ICT Producing and Using Services		0.311
		(1.057)
ICT Producing and Using Manufacturing		2.560**
		(1.18)
Non_ICT_Manufacturing		1.69
		(1.099)
Non_ICT_Services		-0.712
		(1.093)
Rest Marmara		0.56
		(0.634)
Aegean		-0.276
		(0.712)
West and Central Anatolia		-0.977*
		(0.57)
Mediterranean		-0.877
		(0.78)
Rest Anatolia		0.551
		(1.171)
Constant		-2.995*
		(1.529)
Lnsig2u Constant		1.992***
		(0.201)
Observations	436	1,610
Number of id	109	322

*** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses
Note: Modified Wald test for groupwise heteroskedasticity in fixed effect regression model confirms the presence of heteroscedasticityof the each model

Table 3.22. Panel Data Estimation Results of ERP and CRM for Manufacturing and Services Industries

VARIABLES	ERP		CRM	
	Manufacturing	Services	Manufacturing	Services
Firm Size	1.452**	0,231	-1.019***	0,288
	(0.698)	(0.326)	(0.394)	(0.297)
Export Share	-2,400	1,532	-1,277	2,806
	(3.228)	(3.553)	(1.693)	(3.237)
Export share square	3,727	-0,0409	1,907	-1,267
	(3.948)	(4.633)	(2.071)	(3.903)
Software	0,147	-0,0763	0,0201	0,00941
	(0.0952)	(0.0839)	(0.0542)	(0.0710)
R&D	0,0196	0,185	-0,0889	0,153
	(0.120)	(0.229)	(0.0695)	(0.104)
Foreign share	-0,0488	0,116	0.0377*	0,00278
	(0.0717)	(0.140)	(0.0200)	(0.0136)
Regional Agglomeration	-1,022	-1,957	1,230	-0,634
	(4.885)	(3.162)	(2.185)	(2.634)
Observations	176	260	468	346
Number of id	44	65	118	87

*** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses
Note: Modified Wald test for groupwise heteroskedasticity in fixed effect regression model confirms the presence of heteroscedasticityof the each model

3.6.4.4. Panel Data Estimation Results for Narrowband and Broadband Technologies

Table 3.23 shows the fixed effect panel data estimation of narrowband and broadband technologies. As for the estimation of ISDN as a narrowband technology, export share, R&D personnel expenditure, and foreign share have positive and significant effects on the manufacturing sector. Firm size has a negative effect on the use of ISDN in the services sector.

Table 3.23. Fixed Effect Panel Data Estimation for Narrowband and Broadband Technologies

VARIABLES	ISDN		MOBİLE CONNECTION		OTHER FIXED CONNECTION	
	M	S	M	S	M	S
Size	0,665	-0.663*	0.663*	0,197	1.111**	0,452
	(0.588)	(0.361)	(0.397)	(0.288)	(0.493)	(0.363)
Export share	5.427***	-5.877*	3.700**	-2,514	-2,319	-4,815
	(2.106)	(3.395)	(1.667)	(3.069)	(2.080)	(4.770)
Export share square	-5.057**	7.226*	-3.562*	2.959**	1.241*	3.100***
	(2.472)	(3.883)	(2.020)	(3.512)	(2.350)	(6.567)
Software	0,0739	0.119*	0,00735	-0,000884	0,112	-0,0674
	(0.0675)	(0.0655)	(0.0585)	(0.0684)	(0.0819)	(0.0946)
R&D	0.208**	-0,128	-0,0251	-0,0665	-0,0314	0,119
	(0.0920)	(0.193)	(0.0678)	(0.134)	(0.105)	(0.101)
Foreign Share	0,0206	-0,0127	0,0114	0,0120	0,00205	-0,00384
	(0.0135)	(0.0182)	(0.0168)	(0.0126)	(0.0252)	(0.0174)
Regional Accumulation	5,215	-5,904	2,796	4,678	-4,197	3,160
	(3.374)	(4.509)	(2.498)	(4.604)	(3.162)	(4.469)
Observations	308	308	424	304	248	212
Number of id	78	78	106	76	62	53

*** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses. M:Manufacturing S:Services

Note: Modified Wald test for groupwise heteroskedasticity in fixed effect regression model confirms the presence of heteroscedasticityof the each model

3.6.5. Conclusion

In this chapter, firm level determinants of ICT adoption is estimated based on the hypothesis that firm specific factors have lagged effects on adoption. We tested this hypothesis by using two different time lags. In addition, we applied cross sectional and panel data analysis in this thesis. In the cross sectional analysis, we allow a two year lag between dependent variables and explanatory variables. This effect indicates short term effects. In the panel data analysis, the time lag extends to four years which indicates long term effects.

Table 3.24 demonstrates the effects of firm specific factors on technology ownership based on different methodologies. There are various scenarios in terms of the effect of firm specific factors on adoption. First, some firm specific factors have only immediate effects. Second, some firm specific factors have both immediate and long term effects. Third, some firm specific factors have neither immediate effects nor long term effects.

Panel data first differencing methodology give similar results both for the random effects and fixed effects. As far as the results of alternative estimators, firm size and e-training are the two variables that generate positive and significant effects on adoption. Our hypothesis is that scale effects exist before the technology is adopted. The estimation results confirm this hypothesis. In addition, there is no constraint on the time of adoption. Large firms can introduce the resources two year or four year before the adoption. E-training has a similar effect on adoption.

Export share indicates the trade openness of the firm. We expect that export shares have lagged effects on adoption. Therefore, firms learn from their foreign counterparts about the new technology but learning occurs over a period of time. The results of cross section analysis supports this evidence. When it comes to panel data analysis, the effect of export share disappears.

This implies that a firm should adopt the technology two years later after building up related firm specific factors. When the lag becomes four-year, there will be no positive return from trade openness.

Initial software investment provides both immediate effects and long term effects on adoption. Long term effects are valid only for the GLLAMM procedure. The initial software investment does not have significant effects for the alternative estimation of fixed effects. R&D personnel expenditure, foreign share, and e-banking have the same effect on adoption.

Industry dummies are not included in the fixed effects model. As for the cross sectional analysis, services sector regardless of ICT producing or using provides positive and significant effect on adoption. Finally, we generated the regional agglomeration variable for the fixed effect estimation assuming that regional agglomeration could vary from one year to another. On the other hand, it does not have significant results.

As for the effects of firm specific factors on the adoption of specific technologies such as ERP and CRM, there are differences between short term effects and long term effects. Firm specific factors do not generate any significant effect on the adoption of ERP in the long term. This implies that ERP technology should be adopted two years after the firm specific factors are built up. When the estimations are repeated for the manufacturing sectors and the services sectors separately, only firm size has long term effects on the adoption of ERP in the manufacturing sector. This result indicates that scale advantages are substantial for the ERP adoption. In other words, large firms are able to adopt the technology regardless of time constraint. As for the CRM, firm size has negative effects on the adoption of this technology in the manufacturing sector. On the other hand, foreign shares have positive and significant effects on the adoption of CRM in the long term.

As for the effects of firm specific factors on the adoption of old and new technologies, only foreign share, e-banking, e-training and some region dummies have immediate effects on the adoption of ISDN technology. In the long term, export share and R&D personnel expenditure have positive and significant effects in the manufacturing industry. As for the services industry, export shares have negative effects on the adoption of ISDN. Software investments per employee have positive effects on the adoption of ISDN in the services sector.

Export shares have positive effect on the adoption of mobile connections in the manufacturing sector, other variables do not have significant effects on the adoption of mobile connections in the long term.

Table 3.24. Summary of results

Variables	**Two-year lag Cross Section Data Analysis**	**Four-year lag Panel Data Analysis Fixed Effects Estimation**		
	Ordered Logit	Panel Data First Differencing*	Baetschmann et al. (2011) Fixed Effect Estimator	Ferrer-i Carbonell and Frijters (2004)
Firm size	+	+	+	+
Export share	+	+	n.s.	n.s.
Export share square	-	-	n.s.	n.s.
Software	+	+	n.s.	n.s.
R&D	+	+	n.s.	n.s.
Foreign share	+	+	n.s.	n.s.
E-training	+	+	+	+
E-banking	+	+	n.s.	n.s.
Regional Agglomeration	n.a.	n.s.	n.s.	n.s.
Industry		Industry dummies are not used in the fixed effects estimation		
ICT Producing and Using Serv.	+			
Non ICT Services	+			
Non ICT Other	n.s.			
Non ICT Manufacturing	n.s.			
Region		Region dummies are not used in the fixed effects estimation		
Rest Marmara	n.s.			
Aegean	-			
West and Central Anatolia	-			
Mediterranean	-			
Rest Anatolia	-			

Note: Results belong to four-technology model, n.s.(not significant)

CHAPTER 4

EFFECT OF SOFTWARE INVESTMENT ON FIRM EFFICIENCY

4.1.Introduction

In recent years, the share of intangible investments in the manufacturing sector have increased in most European countries such as Germany, the Netherlands, Belgium, Italy, and also Spain and the US while the share of tangible investments have decreased (Corrado et al., 2012). Intangible investments are defined as "claims on future benefits that do not have a physical or financial embodiment" (Lev, 2001). There are several classifications on the types of intangible assets (see Van Ark and Piatkowski, 2004; Young, 1998; Vosselman, 1998; Eurostat, 2001; MERITUM, 2002; EU, 2003; Hulten and Hao., 2008; Cummins, 2005). More recent classification belongs to Corrado et al. (2009). Accordingly, intangibles are composed of three main components as computerized information, scientific and creative property, and economic competencies. While computer software and computerized databases are in the first group, science and engineering R&D, mineral exploration, copyrights and license costs, and other activities for product development such as design and research are in the second group. The third group emphasizes the "soft" part of the intangibles such as brand equity, firm specific human capital, and organizational structure.

Studies that focus on the link between intangible investment and productivity have found that productivity growth increases with intangible investments (Oliner et al., 2007; Corrado et al., 2006, Bosworth and Triplett, 2000; Van Ark et al., 2009; Park and Ginarte, 1997). However, there is little evidence on the effect of software investment on firm efficiency (Bechetti et al., 2003). In this thesis, we analyze the share of software investment on firm efficiency by using dataset for Turkish manufacturing firms in the period 2003-2007. Two main effects were observed in those years. The first is, that the number of firms making software investments had decreased while the intensity of software investment had increased. This result implies that firms which had already made software investments became much more software-intensive in that period. We will investigate whether or not this increase in software investment turns into efficiency gains for manufacturing firms.

Intangible investment conceptually refers to different terms. In fact, most of the intangible investment have been financed by households through education and social activities for their children (Webster, 1999). This term, in some of the literature is mentioned as “invisible assets” referring to the personal networks, reputation, or innovation capability (Adams and Oleksak, 2010). More recent efforts have broadened the definition of intangibles to include software and databases, research and development activities, intellectual property rights, human capital, and organizational structure.

Empirical studies on measuring the effect of intangible investment on efficiency have been increasing since 2000 and applications in various industries are available. Jalava and Pohjola(2008) have found positive effects of intangible investments on Finnish economic growth by using the non-financial business sector data and emphasized the increasing role of the quality of the investment rather than the quantity. The positive effect of intangible investment on economic growth is also observed in cross country studies (Van Ark et al., 2009). They used computerized information, innovative property, and economic competencies to proxy the intangibles and have found that the combined effects of these variables accounts for a quarter of labour productivity growth in the US and some countries in the EU. Park and Ginarte (1997) analyzed another component of the intangibles; intellectual property rights (IPRs). Accordingly, IPRs directly affect the factor inputs such as research and development expenditure and physical capital.

Although there is a set of studies on the other components of ICT such as hardware and telecommunication, little emphasis has been given to the software investment which could also be considered as a productive asset (Basu et al., 2004). In recent years, this component has become capitalized as an expenditure in order to observe its contribution to GDP. According to Dal Borgo et al. (2012), R&D only explains a small share of the knowledge spending while asset training, design, and software have the largest shares especially in the services sector in UK.

In the next section, the empirical literature on determinants of firm efficiency is analyzed. Following that, empirical literature with emphasis on the effect of ICT on firm efficiency is dealt with.

4.2. Empirical Literature on the Determinants of Technical Efficiency

There is extensive literature on the determinants of technical efficiency (see Table 4.1). In this thesis, we focus on a part of those variables such as openness, outsourcing, R&D personnel expenditure, and software investment. The following sections deal with the determinants of technical efficiency at the firm level.

4.2.1. Openness

The term openness indicates the exporting activities of the firm. Production efficiency of firms that compete on the international market is high because competition forces firms to allocate resources more efficiently, to exploit scale economies, and to improve their technology (Balassa, 1978; Feder, 1982; Ram, 1985; Bodman, 1996).

The positive effects of export on firm efficiency are found in some of the literature (Baldwin and Caves, 1998; Taymaz and Saatçi, 1997; Aw and Batra, 1998; Sun et al., 1999; Piese and Thirtle, 2000; Albert and Moudos, 2004; Delgado et al., 2002; Hossain and Karunaratne, 2004) while in others, negative relationships (Grether, 1999) or no relationships are observed (Alvarez and Crespi, 2003). The reason for the negative effects of exports on efficiency can be explained by technological disparities between domestic firms and foreign counterparts.

Sun et al. (1999) found that trade openness of the economy explains regional and industrial variation in terms of efficiency. Economic reforms in China after 1980 targeted coastal regions, therefore, the economy in those regions became exposed to foreign trade that turns into efficiency gains. On the other hand, the effects of export shares increase at a decreasing rate and declines after a certain point (Hossain and Karunaratne, 2004). In addition, when export shares interact with non-production labor, the positive effects of export shares become negative.

4.2.2. Outsourcing expenditure

Outsourcing indicates all subcontracting relationships between firms including hiring temporary labor. Transaction cost approach elaborates the outsourcing activities in terms of cost reduction functionality (Williamson, 1981). Firms can either outsource production activities or business related services. Therefore, they can allocate the resources to the activities which provide a comparative advantage. As a result, firms can attract more highly skilled staff through investment in its core competences.

The effects of outsourcing on firm efficiency is studied in the empirical literature (Heshmat, 2003; Taymaz and Saatçi, 1997). While the positive effects of outsourcing on efficiency are observed in these studies, a large part of these are concerned with the effects of outsourcing on profitability and productivity because outsourcing can produce significant differences in the quality of the final products and sales even if there is no change in the efficiency[38] (Görzig and Stephan, 2002; Lacity and Willcocks, 1998; Gianelle and Tattara, 2009). In addition, long term effects and short term effects of outsourcing can be different. Windrum et al. (2009) argued that in the long term, the productivity of outsourcing firms decreases. They claimed that long term productivity growth depends on how activities are managed within the firm rather than the ownership of the activities. Based on this, it is crucial to make a distinction between outsourcing income and outsourcing expenditure. Outsourcing could be the main activity of the firm that generates a large part of the firm's turnover or the firm may outsource part of its activities to the external suppliers.

4.2.3. R&D personnel expenditure

In the efficiency literature, the effects of research and development (R&D) activities are analyzed by using various proxies such as R&D capital intensity (Kumbhakar et al., 2009), R&D capital stock (Wang, 2007), or R&D expenditure (Perelman, 2005).

[38] 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 and 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.

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 and Levinthal, 1989) is crucial especially for firms operating in capital intensive industries such as electricity, machinery, and chemicals. Besides the other factors, the compatibility of firm specific human capital between domestic firms and foreign counterparts is crucial to fully exploit the spillovers through foreign direct investment (Castillo et al., 2012). Based on this, a positive effect is expected for this variable (Griliches, 1998; Coe et al., 1995; Tassey, 1997; Huan and Liu, 1994).

Table 4.1. A list of Literature on the determinants of firm Efficiency and Expected Signs

Variables	Expected Sign	Motivation	Literature
Openness	+	Small firms with no initial software investment	Aw and Batra (1998)
		Access to foreign market	Sun et al. (1999)
		Learning by exporting is only valid for young exporters	Delgado et al. (2002)
		Greater capacity of utilization, international market competition, and specialization in production	Piese and Thirtle (2000) Albert and Maudos (2004)
	-	When combined with non-production labor its effect on the firm efficiency	Hossain and Karunaratne (2004)
Outsourcing	+	Allocation of resources to the activities that provide comparative advantage	Heshmati (2003) Taymaz and Saatçi(1997)
R&D Personnel Expenditure	+	Absorptive capacity	Cohen and Levinthal (1989)
ICT	+	R&D spillovers from developed countries to developing ones	Coe et al.(1995);Huan and Liu (1994)
		Higher growing firms exploit the benefits of adopting integrated technologies more than lower growing firms	Brassini and Freo (2011)
		ICT generates complementary effects on the variables as human capital and structural change in the different sectors	Castiglione (2011)
		Higher economic growth depends on technological progress	Dimelis et al. (2010)
	n.s.	No significant effect of e-selling on firm's efficiency	Romero and Rodriguez (2010)
Software Investment	+	Software investment increases the scale of firm operations	Bechetti et al. (2003)

4.3. Empirical Literature on the effect of ICT on firm efficiency

Earlier studies focused mainly on solving the Solow Paradox on computer-productivity link. While computer investments continued to increase in the 1970s, productivity has declined sharply, especially in the manufacturing sector. Brynjolffson (1993) determined two factors to explain the paradox. One is related to mismeasurement of outputs and inputs. The problem of measurement is based on underestimating the intangible assets in the production statistics. This problem is encountered in the services sector where the role of services quality in "total output" is broad. The second issue is the time lag needed for the diffusion of technology (David, 1990). According to this, the short term impact of ICT on productivity can be negative or insignificant since the learning effect may not arise in the period that the technology is introduced. For instance, Brynjolffson (1996) analyzed the effects of IT capital and information systems labor on productivity for a later period and found a positive effect.

The 1995s witnessed a sharp increase in US productivity levels which reveal the role of industy in reaching a higher productivity levels. For instance, Van Ark et al. (2003) analyzed the determinants of productivity differences between Europe and the US. Productivity growth in the US is much higher in the period 1995-2000. They observe that the role of ICT producing sectors in productivity growth is crucial while ICT using industries did not have the same effect (Gordon, 2000; Van Ark et al., 2003).

Two main effects of ICT are mentioned in the literature. One is the direct effect which is observed when the capital per worker increases with hardware, telecommunication and or software investment. This process is referred to as "capital deepening". In the period 1995-1998 , the direct effect of IT on average labour productivity increased faster than that of 1990-1995 which was induced by continuous decline in computer prices and a high level of investment, especially in high technology assets and semiconductors (Jorgenson et al., 2000).

After 2000, increase in productivity coincided with a decrease in IT investments. Gordon (2004) argued that productivity growth accelerated in late 1995 because of the improvements in intangible assets and the increase in productivity was exaggerated. Hence, the real productivity growth is not that sharp.

An indirect effect indicates changes in business processes through ICT. According to this, the link between productivity and ICT is established through complementary organizational investments (Brynjolffsson and Hitt, 2000). Bresnahan et al. (2002) went one step further and examined the combined effects of IT, workplace organization, and new products and processes. The focus was whether or not demand for skilled labor increased significantly more than that for unskilled labor. This process is referred to as skilled biased technical change. Accordingly, the effect of IT on demand for skilled labor is much greater when its effect is combined with work organization.

More recent research on IT and productivity tend to reveal the role of external environment of a firm in IT's rate of return and firm productivity (Tambe and Hitt, 2011). Following the hypothesis of the complementary effect of IT in previous research, the external focus of the firm such as the involvement of customers, suppliers, and business partners on the project team or using competitive benchmarks is added as a term into the production function. Therefore, the main trend in ICT studies is shaped within the framework of "complementarity effect" which indicates that IT creates multiple effects as a single input.

As for the link between ICT and efficiency, there are a limited number of studies on the impact of ICT on firm efficiency. As demonstrated by Table 4.2, ICT is defined in different ways in these studies. Castiglione (2011) constructs a binary variable which takes the value of 1 if the firm makes ICT investment. Romero and Rodriguez (2010) also generated a binary variable by using the information on firms'e-buying and e-selling activities. Mouelhi (2009) created an ICT index by using hardware, telecommunication, and software acquisition ratio. Similarly, Vries and Koetter (2011) generated an ICT index varying from 0 to 7 by using internet, intranet, extranet, and webpage ownership. Higher values of the index indicate the advancement of ICT usage. Bechetti et al. (2003) used hardware, software, and telecommunication investments separately. Besides investment in those components of ICT, Shao and Lin (2001) used information systems staff expenditure as a proxy.

4.3.1. Software Investment

The effect of intangible investment on productivity has been studied only recently since the share of intangible investment exceeded the tangible investments. The more recent evidence belongs to Corrado et al. (2012). Accordingly, the effect of intangible investment on economic growth and labour productivity is positive especially in developed countries. However, the effect of intangibles on economic growth or productivity in developing countries in most cases cannot be studied due to the lack of data. In this thesis, we analyze the effect of software component of intangible investment on Turkish manufacturing firms for the years 2003-2007 by using information on software investment. In those years, there has been an increase in software investment intensity while there is no increase in the number of firms that make investment.

The motivation for using this variable is to reveal whether or not investing in specific software generates differential effect on efficiency between software-intensive firms and other firms. There are a limited number of studies that analyzes the effect of ICT (see, Table 4.2). Empirical evidence establishes a positive link between ICT and technical efficiency (Brassini and Freo, 2012; Castiglione, 2011; Dimelis and Papaioannou , 2010; Bechetti et al., 2003; Lee and Barua, 1999; Romero and Rodriguez, 2010; Repkine, 2008; Bertscheck et al., 2006; Criscuolo and Waldron, 2003;Rincon et al., 2005) while no significant effect was observed in some cases (Milana and Zeli, 2002). In addition, the effect of ICT on technical efficiency may not change the technology frontier for countries having a high level of telecommunication investment (Repkine, 2009). To consider the effect of ICT on productivity, the positive effect of computer networks was found (Atrostic and 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 are lower in Japan (Atrostic et al., 2008). In addition, complementarity could exist among the ICT components such as the relationship between information networks and business networks (Motohashi, 2007).

Table 4.2. Firm Level Studies on ICT and Efficiency: Stochastic Frontier Approach (SFA)

Authors	Target population	Result	IT component
Castiglione (2011)	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
Bechetti et al. (2003)	4400 Italian SME's over the period 1995 to 1997	While 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	It indicator is used as a decomposed form;hardware, software, and telecommunication investment
Romero and Rodriguez (2010)	Spanish manufacturing firms in the period 2000-2005	Positive influence of e-buying on efficiency while e-selling has no effect	Binary variable if firms makes e-buying or e-selling
Shao and Lin (2001)	US firms during the period of 1988-1992	Positive effect of IT on efficiency	Hardware investment and information systems staff expenditure
Dimelis and Papaioannou (2010)	17 OECD countries countries in the period 1990-2005	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 assets (OECD, 2008) ICT investment as a share of GDP
Mouelhi (2009)	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
Vries and Koetter (2011)	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 ownership

Table 4.2. Continued

Authors	Target population	Result	IT component
Dimelis and Papaioannou (2010)	17 OECD countries countries in the period 1990-2005	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 assets (OECD, 2008) ICT investment as a share of GDP
Mouelhi (2009)	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
Vries and Koetter (2011)	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

4.4. Methodology on Measuring the Firm Efficiency: Stochastic Frontier Analysis

Productivity is defined as the ratio of output to input. Increase in productivity can be based on technical change, exploitation of scale economies or the combined effect of those sources (Coelli et al., 2005). Technical change indicates the advancement in the technology which is generated by the upward shift in the production frontier. Exploiting scale economies implies the optimal scale therefore; productivity declines if the firm operates at any other point. Efficiency is the component of the productivity (Lovell, 1993).Firms that operate on the frontier are technically efficient.

In this thesis, the effect of software investment on firm efficiency is analyzed by using the stochastic frontier analysis.The literature on productive efficiency dates back to Farrell (1957). 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. As emphasized by Schmidt and Sickles (1984) the term frontier indicates the maximality that it embodies.

There are mainly two approaches for measuring technical efficiency namely Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). The first assigns the nonparametric approach to the frontier. As shown by the Table 4.3, data envelopment analysis (DEA) is the nonparametric frontier estimation which does not impose any restriction for the functional form and there is no specific assumption about the distribution of the inefficiency term. Those features are mentioned as advantages of using DEA to measure efficiency. However, random deviations from the frontier are treated as inefficiency in the DEA approach. Therefore, it is not clear if the lack of efficiency is due to the technical efficiency or statistical noise

(Heshmati and Kumbhakar, 1994). This generates problems due to the fact that measurement errors, omitted variables, or external shocks are represented by a single term.

There is a clear distinction between statistical noise and technical inefficiency in the stochastic frontier approach. Additionally, a specific functional form as Cobb-Douglas or translog is introduced with distributional assumption for the inefficiency term.

Table 4.3. Differences between Stochastic Frontier Analysis and Data Envelopment Analysis

SFA	DEA
• specific functional form (Cobb-Douglas, Translog, or CES) is required • presence of distributional assumption for the inefficiency term • deals with statistical noise allows statistical tests of hypotheses concerning production structure and the degree of inefficiency	• no functional form • no explicit assumption about the inefficiency • whether lack of efficiency is due to technical inefficiency or to statistical noise

An error term is composed of two components such as a normal random error term and a non-negative error term which represents the technical inefficiency (Aigner et al., 1977).

Firms are assumed to differ in terms of production of y and given set of inputs based on the random variation in their ability to utilize the best practice technology. Therefore, the source of the error can be on sided and or input quantity measurement in y.

$$y_i/[x_i;\beta)+v_i] \qquad i=1,\ldots,N \tag{23}$$

v_i represents the symmetric disturbance and it is assumed to be independently and identically distributed $N(0,\sigma_v^2)$.

The error term u_i is assumed to be distributed independently from v_i to satisfy the conditon of $u_i \leq 0$

The frontier is stochastic with random disturbance being the result of favorable as well as unfavorable results. Therefore, the productive efficiency is the ratio of $y_i/[f(x_i;\beta)+v_i]$. Therefore productive inefficieny is distinguished from the other sources of disturbance.

4.4.1.Technical Efficiency

Technical efficiency is defined as the distance of a firm from an efficient frontier (Battese and 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.

Figure 4.1 shows the production frontier demonstrates the relationship between the input and the output which represents the maximum output attainable from each input level. Each point under the production frontier is assigned to an inefficient point. For instance, point A is inefficient since it is possible to increase output without using additional input.

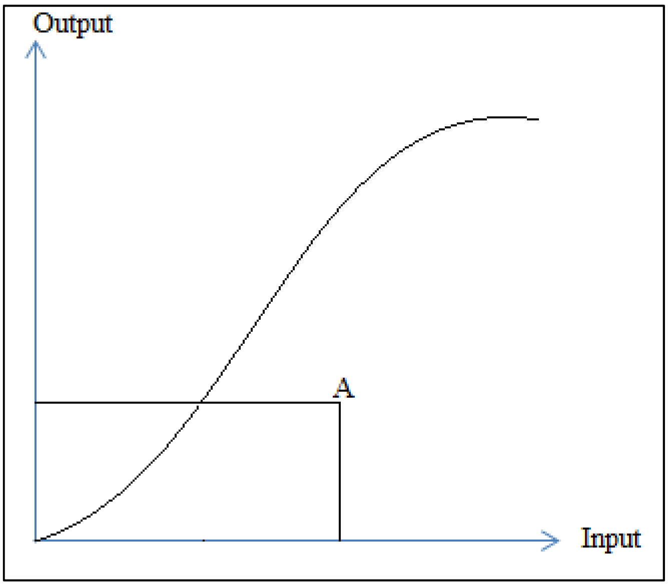


Figure 4.1. Production Frontier

4.4.2. Panel Data versus Cross section

Cross sectional stochastic frontier models are built on restriction assumptions. Schmidt and Sickles (1984) mentioned two of them. One is that cross sectional analysis requires strong distributional assumptions. The other assumption is that technical efficiency is required to be independent from explanatory variables.

Those assumptions are avoidable in the panel specification, other advantages are the exploitation of information for each individual over a time period and the presence of large degrees of freedom (Battese, 1998).

4.4.2.1.Time Varying Technical Efficiency

According to the time varying technical efficiency model, u_{it} varies over time. It is demonstrated as

$$y_{it}=a+\sum_k \beta_k x_{kit}+\varepsilon_{it} \quad (24)$$

$\varepsilon_{it}=v_{it}-u_{it}$

$i=1,2….,N;\ t=1,2….,T;\ k=1,2,…,K$

where i indexes the firm, t indexes the time periods, and k indexes the inputs. y_{it} is the output, x_{kit} are K different inputs. v_{it} variable is assumed to be independent and uncorrelated with the regressors, normally distributed. v_{it} indicates technical inefficiency taking the nonnegative values. $u_{it} iidN^{*}(0,\sigma_u^2)$

4.4.3. Functional Forms

There are two main functional forms used in stochastic frontier applications. These are Cobb Douglas and Translog functional forms.

4.4.3.1. Cobb Douglas Function

Cobb Douglas production function has constant input elasticities and returns to scale for all firms in the sample. The elasticities of substitution for the Cobb-Douglas function are equal to one. Considering the simple form of Cobb Douglas with two inputs namely x1 and x2

$$y=Ax_1^{b1}x_2^{b2} \tag{25}$$

In logarithmic form

$$\ln y=\ln A+b_1\ln x_1+b_2\ln x_2 \tag{26}$$

4.4.3.2. Translog Functional Form

Translog function form is known as flexible functional form.

$$\ln y=\ln A+b_1\ln x_1+b_2\ln x_2+\left(\frac{1}{2}\right)\left[b_{11}(\ln x_1)^2+b_{22}(\ln x_2)^2\right]+b_{12}\ln x_1\ln x_2 \tag{27}$$

4.4.4. Specification Tests

Hypothesis testing can be based on different concerns such as determining the distribution of the technical efficiency, functional form, the presence of technical inefficiency, and the presence of time variant technical efficiency. In order to test these hypotheses, log likelihoods are compared based on the formulation:

$$-2\{\log[\text{likelihood}(H0)]-\log[\text{likelihood}(H1)]\} \qquad (28)$$

4.5. Construction of the Efficiency Variables

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 in this thesis. It includes the data from the years 2003 to 2007. Each dataset has detailed information on sales, revenues, and costs for each firm. At first, 2003-2006 dataset was shared by Turkstat then the 2007 wave was introduced as a single dataset. With the help of a key dataset which includes the common id numbers for the wave 2007 and 2003-2006 dataset, two datasets are merged and after deleting the duplicated observations, 17131 observations remained for each year (85655). Since measuring productivity in the services sector is quite different than that for production sectors, only manufacturing firms are included in this thesis. The number of manufacturing firms in the dataset is 45900.

To construct the variables, the dataset is cleaned of irrelevant observations. In this thesis, capital stock is proxied by depreciation allowances and some observations of this variable have zero values. It assumes that those firms do not have any production activities. Therefore, firms with zero capital stock information in any of the years have been detected and removed from the sample. The same procedure is applied to the employment data. Based on the data collection methodology followed by TURKSTAT, firms employing more than 20 workers have been sampled. Therefore, observations for micro firms with less than 20 workers have been deleted. Moreover, manufacturing industry revenues which are used to construct output variables have been removed from the zero observations. In this study, firms which do not invest in software are excluded. A number of observations have also been also removed following the construction of the variables. Figure 4.2 demonstrates the basis that we use in the data cleaning procedure. For instance observations which exceed 1 for the variable export share have been removed from the sample (see, Figure 4.2). Hence, the final sample size includes 8450 observations with an unbalanced distribution throughout the years.

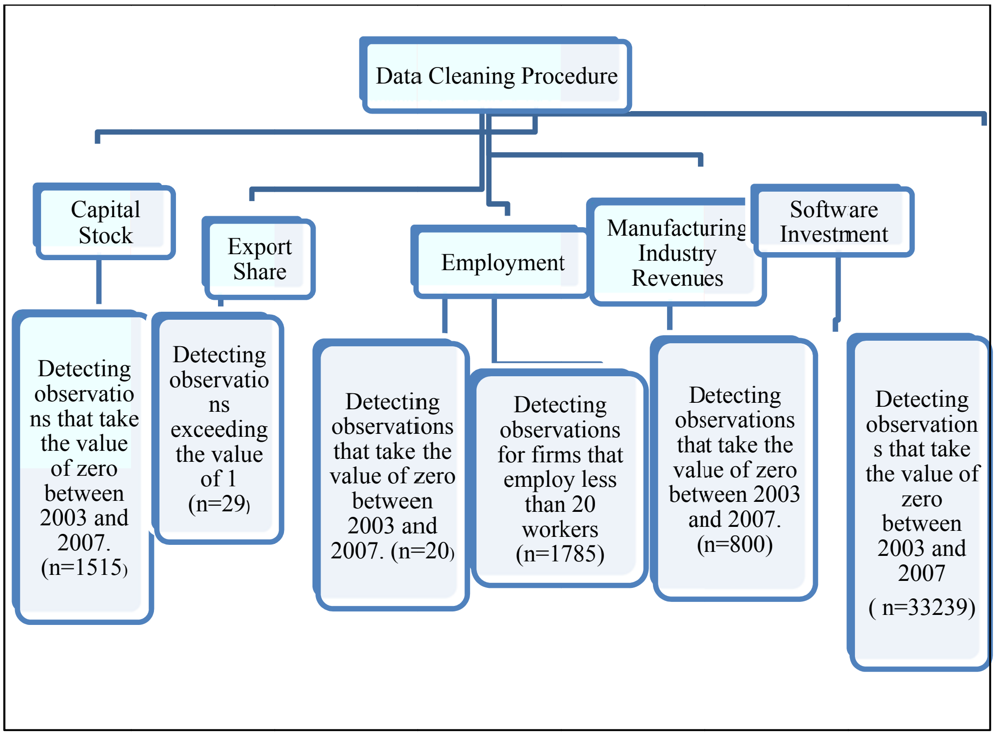


Figure 4.2. Data Cleaning Procedure

Two groups of variables are introduced in this part. The first group includes output and production inputs such as capital stock, labor, raw material, electricity and fuel. The second group is composed of determinants of technical efficiency. These are outsourcing expenditure, export share, R&D personnel expenditure, and software investment. We also included industry dummies both in the production function and the technical efficiency function (see Table 4.5 for the definition of the variables).

4.5.1. Production Variables

Production variables are composed of output, capital, labour, raw material, electricity and fuel (see Appendix 12 for the descriptive statistics). Output is calculated by subtracting the increase in inventories from manufacturing sales. Changes in inventories are calculated by subtracting the value of inventories at the beginning of the year from the value of inventories at the end of the year. This variable is deflated by corresponding sectorial producer price index at four digits.

As far as the input variables are concerned, capital stock, labour, raw material, and electricity and fuels are used to estimate output variable. Two different methodologies used to create a complete capital stock series are mentioned in this thesis. The first is imputing missing values of a variable by using the information on the other variable. To apply this procedure, the presence of a variable with a complete data series is necessary. This methodology was introduced by Gilhooly (2009) to produce firm level capital stock. As shown by Table 4.4, some observations are missing on capital expenditure. To impute the missing values, full observations of the variable are detected and the average capital expenditure is calculated. Then, another variable with a complete data is determined. Employment series, in general, meet this criterion. Average employment value is calculated by using employment values which correspond to the full observations on the capital expenditure. Finally, the average depreciation value is divided by the average employment value and it is multiplied by the employment values to obtain imputed capital expenditure series. This procedure is an alternative way to increase the number of observations in the dataset but it can produce detrimental effects such as multicollinearity between capital stock and employment.

Table 4.4. Constructing Capital Stock Series

Year	Capital Expenditure	Employment	Imputed Capital Expenditure
1985	-	100	1282
1986	-	145	1859
1987	20000	200	20000
1988	13000	190	13
1989	-	250	3205
1990	-17000	200	-17000
1991	-6000	190	-6000
1992	-	230	2949

Source: Gilhooly, (2009).

Note: Average capital expenditure in 1987, 1988, 1990, and 1991=2500Average employment in 1987, 1988,1990, and 1991=195

Average capital expenditure per employee=2500/195=12.82

The second way of calculating capital stock is interpolating the missing observations if the information is avaliable before and after the year where missing information is observed. In this thesis, this method is applied to the depreciation allowances which is a flow variable since the first method has probability of facing multicollinearity.

In order to obtain stock variables, Perpetual Inventory Method is applied in this thesis. First, depreciation growth rate is calculated for the period 2003-2007. Taymaz et al. (2008) calculated depreciation rate as 6.7 percent by using investment series. Then, the initial capital stock is obtained by dividing depreciation to the sum of the average capital stock growth rate and the depreciation rate. Therefore, in order to obtain capital stock for the year 2003, initial capital stock is multiplied by 1 minus the depreciation rate and the deflated depreciation is added to the equation. In the Eq.(29) below,

K_{t-1} indicates initial capital stock. d shows the depreciation rate and I_t is the investment.

$$K_t = (1-d)K_{t-1} + I_t \qquad (29)$$

Nominal values of capital stocks are deflated by the corresponding sectorial producer price indices at four digits. The base year is 2003. This variable is in logarithmic form. Figure 4.3 shows the distribution of geometric mean value of capital stock. This variable tends to increase from 2003 to 2007.

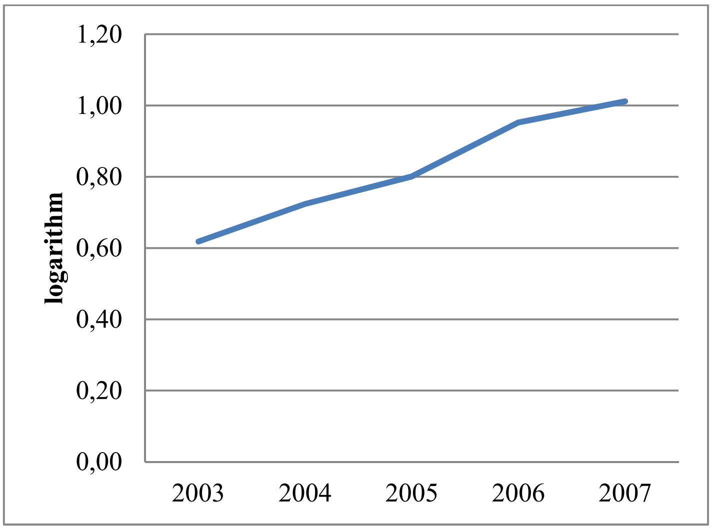


Figure .4.3. Distribution of Capital Stock per Labor

There are two main indicators of labour in the production literature. The first the is number of hours worked and the other is the number of employees in the firm. In the dataset, both indicators are available. However, the indicator of number of hours worked does not give a sufficient variation. Most observations in the dataset have the value of 45 hours. Multiplying this value with the average number of employees does not eliminate the problem of variation. Therefore, average number of employees in the firm is used in this thesis. This variable is in logarithmic form and weighted by its mean. It tends to increase between 2003 and 2007 (see Figure 4.4).

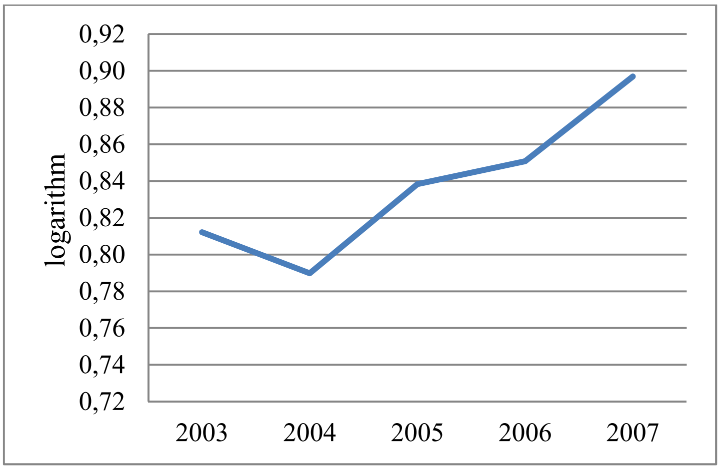


Figure 4.4. Distribution of Labor

Raw materials that are used in the production of goods and services are proxied by the purchase value of raw materials. To obtain the real value of raw material input, it is deflated by sectorial producer price indices at four digits. According to Figure 4.5, the raw material per labour increased between 2003 and 2007 in the manufacturing sector. After 2004, there was a slight decline in the variable. During that period, the production decreased in almost all subsectors of the manufacturing sector such as machinery and electronics.

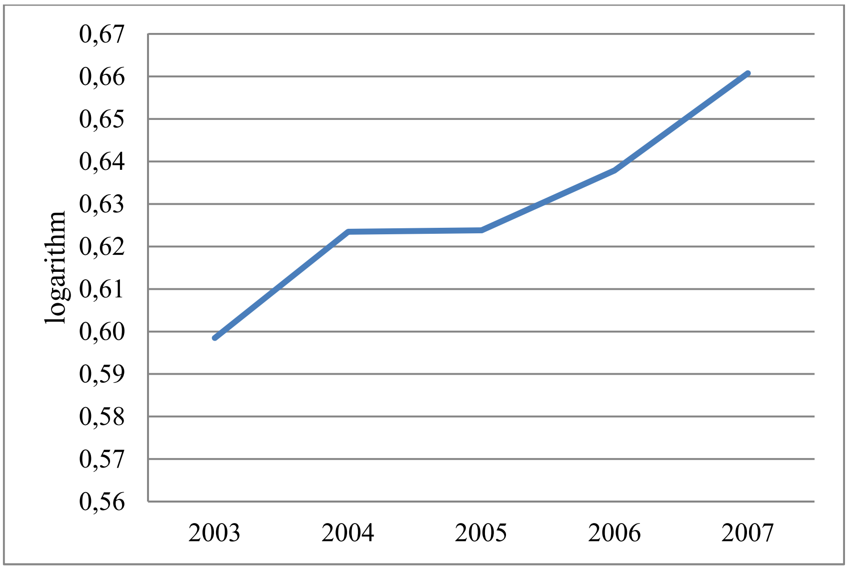


Figure 4.5. Distribution of Raw Materials per Labor

Electricity and fuel as an input factor is measured as the purchased value of electricity and fuel due to the lack of information on consumption in kilowatt-hours which was only available in the 2003 wave of the Annual Structural Business Survey. This question was removed from the survey after that. It is corrected by sectorial producer price index. Figure 4.6 illustrates the distribution of electricity and fuel per labor between 2003 and 2007. Accordingly, there were two sharp decreases in the consumption of electricity and fuel per labor in 2004 and 2006.

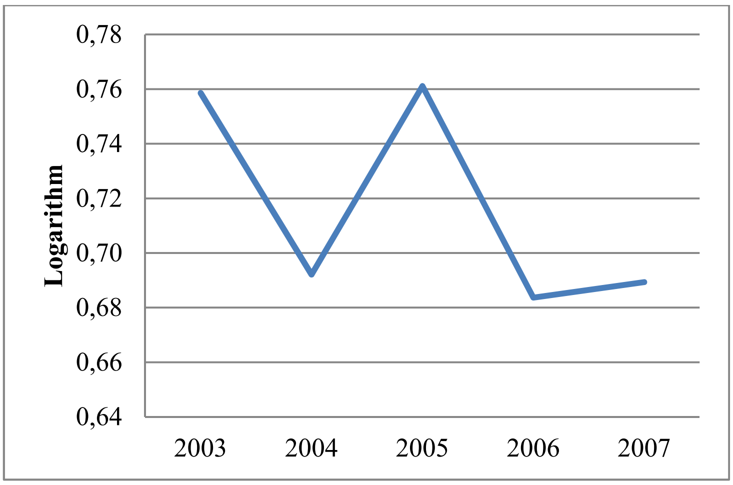


Figure 4.6. Distribution of Electricity and Fuel per Labor

4.5.2. Technical efficiency variables

In the estimation of technical efficiency model, we used foreign ownership, R&D personnel expenditure, software investment per employee, export share, outsourcing expenditure, and time.

As a proxy for human capital, R&D personnel expenditure is used in the estimation of firm efficiency. It is measured as a dummy variable since the R&D personnel expenditure has many zero values. It takes the value of 1 if the firm invests in R&D personnel and zero otherwise. As for the software investment, in the Annual Structural Business Survey (2003-2007), there is a section on total tangible investment and intangible investment. Machinery and buildings are considered as tangible goods. Intangibles are categorized as software investment, R&D investment, and patents. The share of software investment per employee is used in this thesis.

Export share as a proxy for operating in the international market is also considered in the estimation of firm efficiency. It is measured as the ratio of product and services exports to total sales. Outsourcing expenditure is measured by the share of outsourcing expenditure to total expenditure.

4.5.3 Model

We used the 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:

$$y_{it}=a+\sum \beta_k x_{kit}+\varepsilon_{it} \tag{30}$$

$$\varepsilon_{it}=v_{it}-u_{it} \tag{31}$$

$$t=1,\ldots,T \quad i=1,2,\ldots,N$$

$U_{it} \geq 0$

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:

$$U_{it}=\{\exp[-n(t-T)]\}U_i \quad (32)$$

Where n is an unknown parameter to be estimated and U_i are independent and identically distributed non-negative random variables.

4.5.3.1. 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 4.5 displays the variable definitions.

$$\ln(Y_{it}) = \beta_0+\beta_1 \ln(K_{it}) +\beta_2 \ln(L_{it}) +\beta_3 \ln(RM_{it}) +\beta_4 \ln(E_{it}) +\beta_{11}\ln(K_{it})^2 + \beta_{22}\ln(L_{it})^2+\beta_{33}\ln(RM_{it})^2+\beta_{44}\ln(E_{it})^2++\beta_{12} \ln(K_{it}) \ln(L_{it}) +\beta_{13} \ln(K_{it}) \ln(RM_{it})+ \beta_{14} \ln(K_{it}) \ln(E_{it}) +\beta_{23} \ln(L_{it}) \ln(RM_{it})+\beta_{24} \ln(E_{it}) \ln(L_{it})+\beta_{34} \ln(E_{it}) \ln(RM_{it})+v_{it}-u_{it}, \quad (33)$$

$t=1,\ldots, T \quad i=1,2,\ldots,N$

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. 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.

4.5.3.2. Technical Efficiency Function Relationship

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

$$\mu_{it}=\delta_0+\delta_1 \text{Trade Openness}+\delta_2 \text{Outsourcing}+\delta_3 \text{R\&D Personnel}+ \delta_4 \text{Software Investment}+\delta_5 \text{Time Effects}+\delta_6 \text{Industry Effects} \quad (34)$$

In Eq. (34), 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 expenditure is defined as the share of outsourcing expenditure to total expenditure. Research and development (R&D) personnel is measured by a 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.

4.6. Estimation Results for the Effect of Software Investment on Firm Efficiency

All models used in this thesis 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 and 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.

Table 4.6 gives the empirical results of the stochastic frontier and the determinants of technical efficiency of manufacturing firms for the period 2003-2007. The 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 export share, outsourcing expenditure, R&D personel expenditure, 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 technical efficiency. All variables are in logarithmic form.

Starting with the variables in the frontier function, we expected a positive effect of capital stock on output. Therefore, increase in capital intensity indicates the efficient use of machinery which turns into overall increase in the firm efficiency. The output increases with capital stock at 4 percent. The positive sign of capital stock squared indicates that the effect of capital stock increases at an increasing rate.

When the capital stock interacts with labor, raw material, electricity and fuel, the coefficient gives positive, negative, and positive effects, respectively. Interaction with labour is positive 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.

The effect of labor is also positive and significant. In addition, the labor squared gives positive and significant results. Interaction terms with other inputs do give significant results. The positive sign of the squared term of this variable indicates that the effect of labor increases at an increasing rate.

When the labour variable is interacted with the raw material, electricity and fuel separately, the coefficients are negative and positive respectively. The negative sign indicates that the existence of raw material results in a decrease in the effect of labour on output. The interaction effect with electricity and fuel, on the contrary, is positive, implying that these two inputs are complementary.

The coefficient of raw material has the highest share in comparison to other production inputs. The effect of its square term gives positive and significant results 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.

The sign of electricity and fuel is positive and significant. The positive sign of the squared term of this variable indicates that the effect of it on output increases at an increasing rate.

Considering the variables in the inefficiency frontier function, we have export share, outsourcing expenditure, R&D expenditure, software investment, and year dummies. The effect of export share is negative and significant, therefore, exporting activities increase the technical efficiency of the firm.

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.

R&D personnel expenditure is also an important determinant of technical efficiency , implying that R&D intensive firms are more efficient. This finding is in agreement with R&D supporting policy in high technology sectors in Turkey.

The effect of software investment is positive and significant. However, the coefficient is the smallest in comparison to other variables. This indicates that software investment is still not the main factor in explaining technical efficiency since software investment is fairly a new factor of investment.

Time dummies are also introduced in the estimation. Except 2004, all of them are positively related to technical efficiency.

Table 4.7 displays the test results for the models.The first null hypothesis is based on the presence of Cobb-Douglas functional form, therefore, all squared terms and interaction terms are excluded from the model. These tests are applied for each technology group. The likelihood ratios of test statistics are calculated by the formula as

$$-2\{\log[\text{likelihood}(H0)]-\log[\text{likelihood}(H1)]\} \quad (35)$$

If the value exceeds the 5 % critical value, H0 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 parameter gamma is zero, the variance of the inefficiency effects is zero. This indicates that the model is reduced to traditional response functions that include determinants of efficiency into the production function. The test statistics reject this null hypothesis. A key parameter γ is 0.87. 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 sample 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 thesis.

The fourth 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 the inefficiency effect is time invariant. As reported in the Table 4.6, year dummies give negative and significant results for the technical inefficiency. This implies that the null hypothesis is rejected.

Table 4.5. Variable Definition

Output (Q)	Manufacturing sales-changes in finished good inventories (in logarithm)
Capital Stock (K)	Depreciation Allowances (in logarithm)
Labor (L)	Average Number of Employees (in logarithm)
Raw Material (RM)	Total value of intermediate goods (in logarithm)
Electricity and Fuel (E)	Electricity and fuel purchased (in logarithm)
Industry Dummies	High technology industry: Aircraft and spacecraft, pharmaceuticals, office, accounting and computing machinery, radio, TV and communications equipment, medical, precision, and optical instruments
	Medium high technology industry: Electrical machinery and apparutus, motor vehicles, trailers, and semi-trailers, chemicals, railroad equipment and transport equipment, machinery and equipment
	Medium low technology: Building and repairing of ships and boats, rubber and plastics products, coke, reined petroleum products and nuclear fuel, other non-metallic mineral products, basic metals and fabricated metal products
	Low technology industry: Recycling, wood, pulp, paper, paper products, printing and publishing, food products. Beverages and tobacco, textiles and textile products, leather and footwear
R&D Personnel Expenditure	Dummy variable which takes the value of 1 if the firm invests in R&D personnel expenditure
Software Investment per employee	Software investment per employee
Export Share	Share of total product and services exports in total revenues
Outsourcing expenditure	The share of total outsourcing expenditure in total revenues
Time	Dummies for each year from 2004 to 2007. 2003 is a reference year(d_2004, d_2005, d_2006, d_2007)

Table 4.6. Stochastic Production Frontier Estimation Results

A. Frontier Functions	coefficient	standard-error	t-ratio
Constant	-0.07	0.10	-0.68
Capital	0.04	0.00	11.70
Labor	0.22	0.01	36.28
C*C	0.01	0.00	3.70
L*L	0.10	0.01	9.55
K*L	0.00	0.00	0.91
E	0.10	0.00	30.27
E*E	0.02	0.00	19.17
K*E	0.01	0.00	6.21
L*E	0.02	0.00	6.67
RM	0.67	0.00	171.70
RM*RM	0.17	0.00	49.50
K*RM	-0.02	0.00	-10.63
L*RM	-0.13	0.01	-26.38
RM*E	-0.03	0.00	-14.05
High Technology Industry	0.21	0.10	2.08
Medium Low Technology Industry	0.14	0.10	1.42
Low Technology Industry	0.13	0.10	1.30
B. Inefficiency Effects Model	**coefficient**	**standard-error**	**t-ratio**
Constant	-0.86	0.18	-4.67
Software Investment per employee	-0.07	0.01	-7.92
R&D Expenditure per employee	-0.68	0.04	-16.82
Export share	-0.80	0.08	-10.17
Outsourcing expenditure	-6.01	0.21	-28.48
2004	-0.07	0.04	-1.58
2005	-0.40	0.04	-9.80
2006	-1.71	0.18	-9.42
2007	-0.66	0.06	-10.47
Sigma-squared	0.61	0.05	12.03
Gamma	0.87	0.01	76.08

Note: Medium High Technology is the base industry.

Table 4.7. Test results

Null hypothesis	Loglikelihood Value	Test Statistic	Decision
Cobb Douglas production	-2849,83	734,93	H_0 Reject
H_0 : All β's are equal to zero			
No Inefficiency	-3217,29	734,34	H_0 Reject
$H_0 : \gamma = \delta_0 = \ldots\delta_{n=0}$			
Non Stochastic Inefficiency	-1456	688,8	H_0 Reject
$H_0 : \gamma = 0$			
No Inefficiency Effects	-4082,09	459,01	H_0 Reject
$H_0 : \delta_1 = \ldots\delta_n = 0$			
Time Invariant Inefficiency	-2899,03	636,52	H_0 Reject
$H_0 : \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$			

CHAPTER 5

CONCLUSION AND POLICY IMPLICATIONS

This thesis assesses how firm specific factors affect the adoption of ICT by Turkish business enterprises and the impact of software investment on firm efficiency. ICT adoption is measured at three levels. The first is the technology ownership which is an index of multiple complementary technologies. The second is the use of ERP and CRM technologies which serve the specific purposes. The third is the use of narrowband technologies and broadband technologies which are ranked from old to new technologies. Considering the technology ownership model, we hypothesize that firms that build up firm specific factors are much more able to adopt multiple complementary technologies, specific technologies, and broadband technologies.

The descriptive analysis indicates that going from single technology ownership to multiple technology ownership, the effect of firm specific factors on adoption of those technologies increases. It is more probable that large firms adopt multiple complementary technologies. The same effect is observed in other variables such as export share, foreign capital, and R&D personnel expenditure.

In line with the descriptive analysis, the estimation results concerning the firm level determinants of ICT adoption demonstrate that size, initial software investment, R&D personnel expenditure, foreign share, export share, e-banking and e-training activities increase the probability of the adoption of multiple complementary technologies. We also controlled for the effect of environmental factors such as region and the industry that the firm operates in. Based on our results, operating in regions other than Istanbul decreases the probability of adopting multiple technologies in the technology ownership model. As for the use of ERP and CRM technologies, the effect of the firm specific variables such as firm size, export share, foreign share, R&D per employee, e-banking and e-training activities is larger for the ERP users. As for the effect of region and the industry, operating in the rest Marmara is conceived as more advantageous for ERP users. As far as the effect of industry is concerned , operating in the services sector regardless of whether or not it is a ICT producing and using industry, increases the probability of adopting these specific technologies. The use of ERP is more common in the manufacturing industry. The estimation results are in agreement with this.

Considering the use of narrowband technologies and broadband technologies; size, export share, export share square, and R&D per employee do not give significant results on the use of narrowband technologies. Foreign share, e-banking and e-training activities have positive effects on the use of ISDN technology. Firm size, export share, export share square, foreign share, e-banking and e-training activities have positive effect on the adoption of mobile connection and other fixed connection.

We also introduced panel data analysis for the adoption of technology ownership, ERP and CRM usage, and the use of narrowband and broadband technologies. Estimation results concerning the panel data analysis of ICT adoption by Turkish business enterprises can be interpreted based on two effects. These are fixed effects and random effects. As for the fixed effects estimation of the technology ownership model, we obtained different results based on the methodology chosen. Estimation results on panel data first differencing demonstrate that firm size, export share, software investment, R&D personnel expenditure per employee, purposes of ICT usage such as e-banking and e-training have positive and significant effects only in the four technology model. This is similar for the random effect model. The fixed effect estimation results of the alternative estimators, the Bucologit estimator and Carbonell and Frijters(2004) provide different results. For these models, only firm size and e-training have positive and significant effects on technology ownership.

As far as the panel data estimation of the use of ERP and CRM technologies, fixed effects estimation do not give significant results while most of the variables are significant in random effect model. Export share does not give significant result either in the fixed effects model or in the random effects model. Looking at the use of each technology in the manufacturing sectors and services sectors separately, firm size has a positive and significant effect on the use of ERP in the manufacturing sector. There is no significant effect observed in the services sector. For the use of CRM, firm size gives negative and significant effects for the manufacturing sector while foreign share has positive and significant effects on the use of CRM technology in the manufacturing sector.

In this thesis, we also analyzed the firm level determinants of firm efficiency of software intensive manufacturing firms over the period 2003-2007. There are two main observations. First, the number of firms making software investment decreased during the period investigated. Second, firms which already made software investment became more software-intensive in that period. The main question asked is the increase in the intensity of software investment results in efficiency gains for the Turkish manufacturing firms. Production variables are composed of capital, labour, raw material, and energy and fuel. Technical efficiency variables are determined as export share, outsourcing, R&D personnel expenditure, software investment, and time dummies. We followed stochastic frontier approach to reveal the effect of software investment on firm efficiency of firms in the manufacturing sector.

Estimation results concerning the effect of software investment on firm efficiency in Turkey for the period 2003-2007 demonstrate that software investment is crucial for the firm efficiency. Despite its positive and significant effects on firm efficiency, software investment does not generate a great effect as research and development personnel expenditure which is another component of intangible investment. This result shows that the presence of R&D personnel has a more crucial role in firm efficiency than software investment in the software intensive manufacturing firms in Turkey.

To sum up, two main effects are observed regarding ICT adoption which is measured by various proxies in this thesis. First are the *short term effects.* Based on the estimation results of the cross section analysis of adoption, some of the firm specific factors generate immediate effects on the ICT adoption. These variables are export share and export share square. This result implies that exporting activities that are conducted two years before adoption will positively affect adoption. However, this effect will not be continuous when the time lag is extended to four year.

Second are the *long term effects* which are based on panel data analysis. We observed long term effects for some of the firm specific resources. These variables are firm size and e-training activities. This result implies that scale advantages of large firms will still exist in the long term. In addition, firms using the internet for the purpose of e-training will generate facilitating effect on ICT adoption both in the short term and the long term. On the other hand, the fixed effect results are based on the observations that are left over after observations with multiple positive outcomes are dropped, since the duration time is too short to capture the diffusion effect.

As far as the impact of software investment on firm efficiency is concerned, we observe that the intensity of software investment has increased in recent years. On the other hand, its effect on efficiency is not as significant as research and development activities. This result indicates that the presence of R&D personnel is more crucial than software investment.

5.1. POLICY IMPLICATIONS

5.1.1. Definition of the problem

The aim of our thesis is twofold. One is based on the determinants of ICT adoption. The other is based on the effect of software investment on firm efficiency. The adoption behavior of the firms is examined by using three types of ICT indicators. The first is a technology ownership index which is composed of complementary technologies. The second is the use of ERP and CRM technologies. The third is the use of narrowband technologies and broadband technologies.

Based on the complementarity assumption, firms could adopt multiple technologies by using the same amount of resources. Accordingly, firms that use the single technology operate inefficiently. Some firms could not shift from single technology to the two-technology model due to the lack of firm specific factors.

As for the use of ERP and CRM technologies, each technology requires different organizational settings. Based on our results, we can conclude that almost all firm specific variables have greater impact on the use of ERP technology. Accordingly, large firms in the manufacturing sector are much more prone to use ERP technologies while small firms in the services sector are more likely to use CRM technology. In addition, firms located in the rest of the Marmara region tend to use ERP technology while this is not the case for CRM users which are mainly located in Istanbul.

The third is the use of narrowband technologies and broadband technologies. Our results indicate that firm specific factors play a determining role in the use of broadband technologies while the use of narrowband technology does not necessitate using the same amount of firm specific factors.

We can summarize these firm specific factors as internal factors that are established within the firm or external factors that are embedded in the firm's environment. In some cases, the character of the technology requires different combinations of those resources. For instance, resource settings required for the use of ERP technology are not the same for the use of CRM technology. As far as the use of broadband technologies and narrowband technologies is considered, narrowband technology is an old technology and it does not necessitate the presence of firm specific factors like that of broadband technology.

Evolutionary view rather focuses on the mechanisms that generate positive outcomes for firms that reach the related knowledge faster. Therefore, firms that do not have these assets lag behind and single technology users cannot move from single technology to multiple technologies due to the insufficiency of the firm specific factors (Nelson, 2009). These mechanisms are information asymmetry, lock-in, and network externalities. At some point, they generate some effects on adoption of the technology which requires policy intervention for the firms.

Information Asymmetry

The problem of information asymmetry arises when some of the firms have access to the required knowledge for adoption earlier than other firms which do not have such access. The adoption time could be determined based on two conditions. These are profitability condition and arbitrage condition (Stoneman and Diederen, 2002). The profitability condition is based on whether or not it is profitable to adopt a technology in time t. The arbitrage condition is based on whether it is more profitable to wait until a certain date before adoption. The more the firm predicts the adoption time that promise maximum profitability for the firm, the more the firm gains.

Besides profitability conditions and arbitrage conditions, differences in adoption time may occur based on the differences in the learning abilities of the firms. These abilities can be related to the presence of R&D personnel within the firm and the diffusion of technical and market knowledge throughout the firms (Malerba, 2009). Based on our results, single and two technology owner firms do not invest much in R&D personnel which is the barrier that single and two technology owners should deal with.

When there are differences among firms based on information asymmetries, the intervention strategy of the government could be supporting the formation of advanced human capital through regulations in the education system, university training in the new fields, and continuous retraining. At the macro level, the government could focus on building up flexibility within the educational system. At the meso level, the related institutions such as the Ministry of Education, NGO's, school directors/university rectors should come together to discuss how academic programs from pre-school education to university education could be designed in a way that is open to new research fields and interdisciplinary research. At the micro level, government could support the R&D activities of the firms that focus on producing complex technologies.

The problem of lock-in

Policy makers could be forced to deal with the situation that firms lock into an inferior technology since firms with accumulated capabilities in certain products and technologies are reluctant to consider radical changes in their productions (Malerba, 1996). In our study, single and two technology users can fall into the trap of relying on the same technology regardless of its efficiency. In this case, public policy may help these firms by supporting basic research in universities; by upgrading the level of advanced human capital; and by using public procurement as a way to trigger firms learning new technologies.

Network Externalities

In the case of technology adoption, we can consider two types of externalities. These are negative externalities and positive externalities. Negative externalities arise when the adoption of a technology by one firm affects the profits of other firms but this is not taken into account in the firm's decision to adopt (Stoneman and Diederen, 2002). Therefore, the adoption decision of a single firm negatively affects the profits of other firms if the early adoption leads to preemption.

The adoption may also have positive externalities. Adoption can generate information flows which may spill over into the rest of the industry. For some technologies, the positive externalities increase when the number of users increases. The effect of positive externalities on other firms depends on the preexisting network infrastructure. If the firm does not have the required infrastructure, it could not benefit from the technology that is adopted by another firm. The strategy for the policy intervention could be to support the early adopters for the provision of network infrastructure(Stoneman and Diederen, 2002). In addition, government procurement could be a proper instrument to help the establishment of early standards on the new technology.

5.1.2. The necessity of policy formulation in the adoption of ICT

In the case of adoption of ICT, the necessity of formulating a policy emerges as a result of inefficient use of firm specific factors by some group of firms. For our case, single and two technology owner firms work inefficiently because our previous results show that the effect of firm specific factors on adoption is negative for single and two technology owners. In Turkey, 99.9% of the firm population consists of resource-limited small and medium sized enterprises (SMEs). In our study, single and two technology owner firms are mainly SMEs. Our results indicate that with an influential policy intervention, the single and two technology owner firms can accomplish the technology adoption benefits of the three and four technology owners. Our policy formulation rests on short term and long-term effects. Table 5.1 demonstrates the time dependent effects of firm specific variables on adoption variables. Table 5.2 shows the policy implications.

In the short term, almost all firm specific variables have positive effect on the ownership of complementary technologies. In the long term, only firm size and e-training activities exhibit a positive effect on technology ownership [39]. Policy intervention should be directed at regions other than Istanbul since those regions are in disadvantageous position with respect to Istanbul.

The first issue is related to firm size. Large firms are more inclined to adopt the technology earlier than the other firms. In most cases, they are linked to a large network that provides recent information on the new technologies. Small firms may not access the up-to-date information. Those firms should deal with the problem of information asymmetry.

Based on our results, scale effects on the adoption variables are observed both in the short term and the long term. Therefore, it is necessary to design a separate short term and long term policies in terms of scale effects. In our case, policy intervention targets SMEs because they are not able to exploit the scale advantages.

[39] Hall et al. (2010) fixed effect

At the macro level, a set of regulations in the labour market targeting small firms could be designed to reduce the labour costs of these firms. Providing financial support to those firms could be one of these mechanisms. At the meso level, these regulations should be encouraged by an intermediary organization. At the micro level, firm could consider the reallocation of the firm specific costs.

In practical terms, we propose an incentive program namely "Conditional Incentive Program" based on supporting single and two technology owner firms which are composed of SMEs. The support policy targeting SMEs could be implemented by the Republic of Turkey-Small and Medium-Sized Enterprises Development Organization (KOSGEB). Based on Pavitt's taxonomy[40], the majority of the firms in our study are supplier dominated firms which rely on external sources to innovate new product or process. This policy could be directed at product or process innovators since these firms need to be involved in networking with the new suppliers and customers. In the short term, KOSGEB should give training to single and two technology owner firms about the advantages of having three and four technology. At the end of the training program, KOSGEB could provide subsidy to firms that would prepare the strategic plans. The eligibility criteria to receive the subsidy could be based on the countability of the advantages of having three and four technology. After that, KOSGEB could monitor those firms for two years. In the long term, those firms were supposed to expand their size.

The second issue is related to exporting activities. Single and two technology owner firms commonly produce for domestic markets. Export share of those firms are low which negatively affects the adoption of ICT.

[40]Pavitt's taxonomy categorizes mostly large industrial firms along trajectories of technological change according to sources of technology, requirements of the users, and appropriability regime (Pavitt, 1984). The taxonomy aims to classify innovation modes according to different sectoral groups and the flow of knowledge between such groups.

There are a set of advantages of exporting activities in terms of adoption such as learning about the new technology through external links. These firms are not able to exploit the positive network externalities. Based on the literature on network externalities (Katz and Shapiro,1985), the benefits of adopting the technology increases with the number of adopters. Exporting activity is a way of being a part of a large network. It facilitates the development of communication abilities of the firm and it helps firms develop search capabilities. The most prominent effect of exporting activity on adoption is that it provides the recent information on the new technology. In this study, single and two technology owner firms with low exporting activities, are deprived of those positive network externalities.

As demonstrated in Table 5.1, there is a variation among adoption variables in terms of the effect of export share. It has short term effect on technology ownership and on the use of erp and crm technologies while the use of mobile connection sustains short term and long term effects of exporting activities.

In the technology ownership model, the most disadvantageous firm groups are single and two technology owners which are less visible in the international markets. Low level of exporting activities negatively affects the adoption. In our case, to increase the adoption rate of the single and two technology owners, the current exporting activities of these firms should be examined in detail by the related institution.To illustrate, the Ministry of Economy could authorize the Exporters' Assembly to prepare a market search report which is based on information about the content of the single and two technology owner firms'exporting activities such as firms' exporting partners and exporting products or services.

During the preparation of this report, representatives from exporters' associations could do an interview with the single and two technology owners to determine their awareness in the current incentives supplied by the Ministry of Economy. Firms that are reluctant to use the incentives could be asked about the main barriers that impede their involvement in the system. For instance, are single and two technology owner firms aware of the credit system offered by the Ministry of Economy that is designed to decrease the initial costs of adoption? Another issue concerning exporting activities is the foreign language. Whether or not single and two technology owners have a qualified staff with language skills could be determined during the interview. If there is a need for skilled staff, university students with related skills could be employed in these firms. This policy application is crucial both in terms of building up human capital and eliminating one of the barriers to the international trade of single and two technology owner firms.

Based on our results, initial software investment is crucial for the adoption of complementary technologies. Considering the strategic importance of the prior investment, availability of financial resources is necessary, especially for small firms, at the stage at which they begin to operate. Based on our results, the effect of initial software investment increases in a model in which multiple technologies are introduced. This implies that prior investment is critical and generates incremental effects when complementary technologies are adopted at the same time. The policy intervention will target SMEs that are not able to invest in software investment. Those firms due to the lack of initial ICT infrastructure could face the problem of information asymmetry and lock-in. Without prior knowledge on the technology, those firms will lag behind the other firms and lock-in the inferior technology.

The effect of initial software investment on adoption is positive and significant only in the short term. This result contradicts with Geroski (2000). He argued that the adoption path of the software and hardware technologies are different. While the adoption of hardware is faster at the begining, it tends to decline after some point. Considering the software technology, the adoption speed becomes faster at the later stage. In our study, the effect of initial software investment on adoption exists at the begining. Our result indicates that the adoption of the technologies included in our study necessitates the continuous improvement. Therefore, initial investment in software should be introduced two year before the adoption of the technology. When the time lag extends to four year, initial software investment does not generate any significant effect on adoption.

Due to the low initial software investment, single and two technology owner firms do not move to the adoption of three and four technology levels. The policy intervention will target single and two technology owner firms which cannot bare the initial costs of adoption. Accordingly, single and two technology owner firms could collaborate on sharing initial costs of software investment. KOSGEB as an intermediary organization could identify those firms that have common needs and bring them together.

The results of the current study also draws attention to the necessity of R&D personnel. Based on our results, the effect of R&D personnel expenditure increases the adoption of three and four technology usage and the firm efficiency. In the efficiency analysis, we observe the positive and large effect of R&D personnel on firm efficiency as well.

As far as the policy intervention for supporting R&D personnel is concerned, the formal and informal education programs for R&D personnel should be designed according to the needs of the market at the macro level ICT-related research and development activities of the software firms, specifically R&D staff, should be encouraged. At the micro level, to increase the number of IT staff and to organize the formal/informal training programs are two main policy interventions to encourage internal R&D activities.

Based on the prominent role of R&D personnel in the ICT adoption, we propose a revision in the policy of KOSGEB that supports innovators. Our policy could help KOSGEB set criteria for the support. KOSGEB could support three and four technology users because R&D personnel expenditure is inefficient for single or two technology users. This condition will motivate those firms to upgrade their level of technology usage and move to the multiple technology usage.

The role of foreign share is crucial in terms of their network effects.There are various advantages of foreign capital for the firms in the developing countries. The presence of foreign capital facilitates the diffusion of the knowledge in the developing countries. Based on the results of this thesis, a small percentage of the sample is composed of foreign owned firms. However, its effect on using multiple complementary technologies is positive. This indicates that single and two technology owner firms with domestic capital may exploit the benefits of foreign capital through networking with foreign owned firms.

In Turkey, there are some institutions that could bring foreign and domestic firms together. International Investors Association (YASED) which is a non-profit organization with members from international firms operating in Turkey is one of them. YASED and KOSGEB could initiate a project to create a collaborative type of relations between domestic firms and foreign firms.

The region and the industry in which the firms operate are another factors that policy maker could take into account when designing a policy. Based on our results, there are regional disparities among firms in terms of ICT adoption. Some regions such as Istanbul benefit from regional agglomeration since the number of ICT firms is largest in that region. Firms in the disadvantageous regions could be deprived of positive network externalities such as information spillovers among firms located in the same region (Jaffe et al. 1993;Guiso and Schivardi, 2000). Based on the features of Marshallian district[41], knowledge related activities do not travel freely. Conversely, those activities become localized and the knowledge is assembled rather than shared.

At the macro level, encouraging the use of multiple technologies by firms in the disadvantageous regions could be used as a policy to reduce the regional disparities. At the meso level, regional development centers could facilitate networking between firms in Istanbul and the firms in the disadvantageous regions.

In technology development centers where these firms are densely populated, it is expected that firms exploit the advantages of the proximity. In Turkey, a large share of software developer firms are located in the technology development centers in Ankara. ODTU, Bilkent, Hacettepe, and Gazi University are such examples of these centers. Based on our results, firms in the West and Central Anatolia lag behind Istanbul in terms of adoption which contradicts to the assumption about positive effect of proximity. Istanbul keeps the advantage of the adoption although a large number of firms in the software industry have no branch in technology development zones. This implies that besides proximity there could be other mechanisms that ease the adoption of the firms located in Istanbul.

[41] Marshallian district refers to the firms clustered in the same region and concentrated in the certain products.There are two main characteristics of Marshallian districts. One is the high degree of vertical and horizontal specialization. The other is the reliance on market mechanism for exchange of information. They are composed of small firms and focus on single function of the production chain.

The policy intervention will target firms that are not able to exploit the advantages of being in the technology development centers. At first, firms in Ankara could be considered. Based on the AKA(2011) report, software firms in Ankara declare that operating in Ankara is advantageous considering the presence of strategic sectors such as defense industry which heavily relies on ICT products and services. On the other hand, these benefits could dissappear due to the lack of diversity in the market in Ankara. Firms in Istanbul are much able to diversify their products because they are connected to a more diversified customer profile which is a threat for software firms in Ankara.

As a policy intervention, KOSGEB with the cooperation of technology development centers could determine firms operating in the technology development centers in Ankara. These firms can be trained to develop skills which can be used for building up a diversified marketing strategy.

There are some differences across industries in terms of ICT adoption as well as across regions. At the macro level, the number of firms in the non-ICT industries can be determined. After that, they should be encouraged to use the complementary technologies.

As far as the purposes of ICT usage are concerned, the policy intervention could target firms that do not use online banking and training for the firm activities. Since conducting these activities through the internet will result in reduction in costs, raising awareness to increase the use of internet for the e-training and e-banking activities and enhancing reward mechanism could be used as a policy tool at the macro level. At the meso level, information meetings could be organized by the regional development centers. At the micro level, on the other hand, cost-benefit analysis of using internet for e-training and e-banking could be implemented.

In practical terms, related banks that supply credits to the firms could be the authorized to do interview with the firms that do not use e-banking activities in order to reveal their attitudes towards online banking. Using e-banking will provide mutual benefits for both sides. These banks could organize training programmes that compensate the needs of those firms. To increase the number of firms that use online banking facilities will decrease the personnel costs of these banks in the long term.

E-training is particulary crucial since its effect on the adoption of the technology is sustainable.This implies that carrying out training activities on the internet will ease the adoption both in the short term and long term. The policy intervention could target firms that do not use the online training facilities. In the short term, KOSGEB could make interviews to reveal the firms' attitudes towards online training programmes. Based on the results of the interview, KOSGEB and companies that supply online training services organize an orientation program targeting firms that do not use e-training activities. In the long term, KOSGEB can monitor these firms to evaluate whether or not there has been any improvement in the adoption behavior of these firms.

Table 5.1.Time-dependent effects of firm specific variables on adoption variables

	Firm specific variables							
Adopiton Variables	**Firm size**	**Export share**	**Export share square**	**Software**	**R&D**	**Foreign share**	**E-training**	**E-banking**
Technology Ownership	short term long term	short term	short term	short term	short term	short term	short term long term	short term
ERP and CRM	short term long term	short term	short term	short term	short term	short term long term	short term	short term
ISDN	long term				long term	short term	short term	short term
Mobile Connection	short term long term	short term long term	short term long term	short term		short term	short term	short term
Other Fixed Connection	short term long term		short term long term	short term	short term	short term	short term	short term

Note: region and the industry dummies are not used in the table since they are not included in the estimation of long term effec

Table 5.2. A List of Policy Implications

Firm Specific Factors	Expected Effect	Target Group	Problem	Policy Initiative(s)	Policy Implementation
Firm size	Scale	Small and medium size enterprises(SMEs) Supplier-dominated Single and two technology owners	Information asymmetry	Ministry of Science, Industry, and Technology KOSGEB	Conditional Incentive Program
Export	Visibility in the international market	Small and medium size enterprises(SMEs) Supplier-dominated Single and two technology owners	Network externalities	Ministry of Economy Exporters' Assembly Related Exporters' Association	i. Market Research Reportii. In-depth interviews with single and two technology owner firms
Foreign Share	Spillover	Domestic firms	Network externalities	International Investors Association KOSGEB	Setting up collaboration network
Industry Dummies		Firms in the industrial districts			
Region Dummies		Firms in the technoparks			
E-banking E-training	Reduction in transaction cost	Firms that do not use e-banking and e-training	Misallocation of the resources	Banks and training institutions	Determining the barriers to use e-banking and e-training
R&D	Human capital	Firms invest in R&D personnel	Information asymmetry Lock-in	Ministry of Science, Industry, and Technology KOSGEB	Support the Best Program (SUB)
Software Investment	"ICT infrastructure"	Single and two technology owner firms	Information asymmetry Lock-in	Ministry of Science, Industry, and Technology KOSGEB	Developing common resource pool for the software licenses and training

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.

APPENDICES

Appendix 1

A.1.1. Multinomial Logit results for Technology Ownership Model

VARIABLES	(one technology)	(three technology)	(four technology)
Firm size	-0.210***	0.259***	0.510***
	(0.0379)	(0.0382)	(0.0455)
Export share	-1.434	1.754*	1.139
	(0.953)	(0.962)	(1.042)
Export share square	2.061	-2.903*	-1.647
	(1.575)	(1.592)	(1.741)
Initial software inv.	-0.138***	0.0714***	0.112***
	(0.0285)	(0.0219)	(0.0240)
Foreign share	-0.00422	0.00898***	0.0122***
	(0.00335)	(0.00227)	(0.00230)
R&D	-5.902*	-0.276	3.606***
	(3.315)	(1.212)	(1.014)
E-banking	-0.475***	0.473***	0.570**
	(0.118)	(0.182)	(0.241)
E-training	-0.312***	0.546***	0.792***
	(0.0934)	(0.0964)	(0.111)
ICT_Producing and Using Services	-0.0662	0.181	0.231
	(0.141)	(0.154)	(0.182)
Non ICT Services	-0.514***	-0.159	0.205
	(0.153)	(0.168)	(0.192)
Non ICT Other	-0.0648	-0.137	-0.0520
	(0.182)	(0.216)	(0.269)
Non ICT Manufacturing	0.180	0.0474	0.127
	(0.138)	(0.146)	(0.169)
Rest Marmara	-0.0214	0.130	-0.107
	(0.145)	(0.145)	(0.170)
Aegean	0.216	0.0583	-0.282
	(0.139)	(0.149)	(0.178)
West and Central Aantolia	0.111	-0.207	-0.601***
	(0.133)	(0.144)	(0.183)
Mediterranean	0.433***	-0.438**	-0.569**
	(0.163)	(0.210)	(0.248)
Rest Anatolia	0.528***	-0.457**	-0.725**
	(0.161)	(0.227)	(0.295)
Constant	1.325***	-2.702***	-4.776***
	(0.227)	(0.284)	(0.366)
Wald chi2	721.24		
Prob>chi2	0.000		
Pseudo R2	0.11		
Observations	3633	3633	3633

*** p<0.01, ** p<0.05, * p<0.1, Robust standard errors in parentheses
(teknoloji_sahip==2 is the base outcome), Base region is Istanbul

Appendix 2

A.2.1. Marginal effects for Multinomial Logit

VARIABLES	(one technology)	(two technology)	(three technology)	(four technology)
Firm size	-0.0686***	-0.0283***	0.0418***	0.0551***
	-0.00657	-0.00691	-0.00598	-0.00439
Export share	-0.396**	-0.0723	0.348**	0.12
	-0.162	-0.181	-0.147	-0.102
Export share square	0.591**	0.139	-0.566**	-0.163
	-0.266	-0.301	-0.242	-0.17
Initial software investment	-0.0329***	0.00172	0.0167***	0.0145***
	-0.00482	-0.0046	-0.00339	-0.00238
Foreign share	-0.00165***	-0.00101	0.00144***	0.00122***
	-0.000568	0	-0.000342	-0.000217
R&D	-1.190**	0.433	0.174	0.584***
	-0.596	-0.384	-0.24	-0.134
E-banking	-0.142***	-0.00243	0.0867***	0.0575***
	-0.0253	-0.0265	-0.0222	-0.0173
E-training	-0.110***	-0.0613***	0.0879***	0.0834***
	-0.015	-0.0175	-0.0152	-0.0119
ICT Producing and Using Services	-0.0291	-0.0222	0.0285	0.0229
	-0.0233	-0.0278	-0.0248	-0.0196
Non ICT Services	-0.0861***	0.05	-0.00883	0.0449*
	-0.0222	-0.0305	-0.0258	-0.0233
Non ICT Other	-0.00323	0.0215	-0.0182	-4.62E-05
	-0.0311	-0.0383	-0.0324	-0.0277
Non ICT Manufacturing	0.0273	-0.0289	-0.00536	0.00693
	-0.024	-0.0268	-0.0221	-0.0172
Rest Marmara	-0.00814	-0.00493	0.0273	-0.0143
	-0.0242	-0.0279	-0.0234	-0.0154
Aegean	0.0466*	-0.0154	0.00443	-0.0357**
	-0.0257	-0.0272	-0.0233	-0.0147
West and Central Anatolia	0.0496**	0.0324	-0.0274	-0.0547***
	-0.0253	-0.0264	-0.0213	-0.0136
Mediterranean	0.132***	0.00336	-0.0793***	-0.0556***
	-0.0352	-0.034	-0.0254	-0.0169
Rest Anatolia	0.159***	-0.00506	-0.0852***	-0.0685***
	-0.0349	-0.0352	-0.0263	-0.0174
Observations	3,633	3,633	3,633	3,633

Appendix 3

A.3.1. Test results of goodness of fit

fitstat, using (m0)force OLOGIT VERSUS MLOGIT

Measures of Fit for ologit of teknoloji_sahip

	Current	Saved	Difference
Model:	ologit	mlogit	
N:	3633	3633	0
Log-Lik Intercept Only	-4873.758	-4873.758	0.000
Log-Lik Full Model	-4384.181	-4356.243	-27.937
D	8768.362(3613)	8712.487(3579)	55.875(34)
LR	979.155(17)	1035.030(51)	55.875(34)
Prob > LR	0.000	0.000	0.010
McFadden's R2	0.100	0.106	-0.006
McFadden's Adj R2	0.096	0.095	0.001
ML (Cox-Snell) R2	0.236	0.248	-0.012
Cragg-Uhler(Nagelkerke) R2	0.254	0.266	-0.013
McKelvey & Zavoina's R2	0.244	.x	.
Variance of y*	4.349	.x	.
Variance of error	3.290	.x	.
Count R2	0.434	0.432	0.002
Adj Count R2	0.120	0.117	0.003
AIC	2.425	2.428	-0.003
AIC*n	8808.362	8820.487	-12.125
BIC	-20850.341	-20627.489	-222.851
BIC'	-839.792	-616.941	-222.851
BIC used by Stata	8932.318	9155.169	-222.851
AIC used by Stata	8808.362	8820.487	-12.125

Difference of 222.851 in BIC' provides very strong support for current model.

Note: p-value for difference in LR is only valid if models are nested.

Appendix 4

A.4.1. Test result of LR

```
LR TEST
xi: omodel logit teknoloji_sahip   lnfirmsize lnexportshare lnexportsharesquare
lnICTinvestemntperemployee foreign_share lnargepersonel
ICT_ProUsing_Manufacturing ICT_ProUsing_Services Non_ICT_Services
Non_ICT_Other Non_ICT_Manufacturing banka eğitim i.region
note: ICT_ProUsing_Manufacturing dropped because of collinearity
Approximate likelihood-ratio test of proportionality of odds
across response categories:
      chi2(34) =    52.49
    Prob > chi2 =   0.0223
```

Appendix 5

A.5.1. Brant test

Variables	**chi2**	**p>chi2**	**df**
All	52.42	0.023	34
Firm Size	6.08	0.048	2
Export Share	1.75	0.42	2
Export Share Square	2.01	0.38	2
Initial Software Investment	6.54	0.04	2
Foreign Share	3.5	0.17	2
RD Personal Expenditure	5.93	0.05	2
E-Banking	0.46	0.8	2
E-Training	3.94	0.14	2
Non ICT Manufacturing	1.81	0.4	2
ICT Producing and Using Services	0.42	0.81	2
Non ICT Services	5.64	0.06	2
Non ICT Other	0.41	0.81	2
Rest Marmara	2.08	0.36	2
Aegean	1.98	0.37	2
West and Central Anatolia	2.68	0.26	2
Mediterranean	0.28	0.87	2
Rest Anatolia	0.16	0.92	2

Appendix 6

A.6.1. Estimation results for CRM

	(1)	(2)	(3)
VARIABLES	crm	crm	crm
Firm size	0.0301***	0.0318***	0.0323***
	(0.00490)	(0.00486)	(0.00483)
Export share	-0.0300	0.306**	0.304**
	(0.116)	(0.123)	(0.122)
Export share square	-0.0464	-0.517**	-0.513**
	(0.200)	(0.205)	(0.203)
Initial Software Investment per emp.	0.0112***	0.0109***	0.0107***
	(0.00294)	(0.00284)	(0.00284)
Foreign share	0.00107***	0.000946***	0.000883***
	(0.000255)	(0.000246)	(0.000248)
R&D Personnel Exp.	0.501***	0.450***	0.471***
	(0.129)	(0.129)	(0.130)
ICT_Producing and Using Services		0.0829***	0.0737***
		(0.0230)	(0.0226)
Non ICT Services		0.129***	0.121***
		(0.0273)	(0.0270)
Non ICT Other		-0.0634***	-0.0645***
		(0.0243)	(0.0240)
Non ICT Manufacturing		-0.0266	-0.0261
		(0.0190)	(0.0191)
E-banking	0.0681***	0.0618***	0.0595***
	(0.0176)	(0.0177)	(0.0179)
E-training	0.112***	0.107***	0.107***
	(0.0131)	(0.0129)	(0.0129)
Rest Marmara			-0.0261
			(0.0179)
Aegean			-0.0720***
			(0.0156)
West and Central Anatolia			-0.0392**
			(0.0170)
Mediterranean			0.0120
			(0.0249)
Rest Anatolia			0.0132
			(0.0262)
Observations	3,633	3,633	3,633

Appendix 7

A.7.1. Estimation results for ERP

VARIABLES	(1)	(2)	(3)
Firm size	0.102***	0.103***	0.102***
	(0.00688)	(0.00694)	(0.00692)
Export share	1.043***	0.750***	0.723***
	(0.149)	(0.162)	(0.163)
Export share square	-1.441***	-1.059***	-1.010***
	(0.258)	(0.273)	(0.274)
Initial Software Investment per emp.	0.0336***	0.0332***	0.0302***
	(0.00390)	(0.00390)	(0.00393)
Foreign share	0.00272***	0.00273***	0.00252***
	(0.000398)	(0.000401)	(0.000411)
R&D Personnel Exp.	0.568***	0.561***	0.556***
	(0.207)	(0.204)	(0.209)
ICT Producing and Using Services		-0.0528**	-0.0399
		(0.0254)	(0.0258)
Non ICT Services		-0.0662**	-0.0477*
		(0.0266)	(0.0276)
Non ICT Other		-0.169***	-0.155***
		(0.0275)	(0.0289)
Non ICT Manufacturing		0.0199	0.0208
		(0.0246)	(0.0249)
E-banking	0.139***	0.140***	0.130***
	(0.0237)	(0.0235)	(0.0241)
E-training	0.127***	0.124***	0.133***
	(0.0169)	(0.0170)	(0.0171)
Rest Marmara			0.130***
			(0.0280)
Aegean			-0.0818***
			(0.0237)
West and Central Anatolia			-0.0555**
			(0.0247)
Mediterranean			-0.109***
			(0.0300)
Rest Anatolia			-0.0749**
			(0.0329)
Obervations	3633	3633	3633

Appendix 8

A.8.1. Test results for ISDN

VARIABLES	(1)	(2)	(3)
Firm size	0.00545	0.00486	0.00538
	(0.00533)	(0.00533)	(0.00534)
Export share	0.0763	0.217	0.207
	(0.125)	(0.135)	(0.135)
Export share square	-0.0959	-0.286	-0.287
	(0.212)	(0.224)	(0.224)
Lnitial Software Investment per emp.	-0.00366	-0.00363	-0.00407
	(0.00334)	(0.00331)	(0.00332)
Foreign share	0.000759***	0.000718**	0.000690**
	(0.000291)	(0.000291)	(0.000292)
R&D	-0.00778	-0.00746	-0.00676
	(0.00726)	(0.00721)	(0.00721)
ICT Producing and Using Services		0.0198	0.0218
		(0.0217)	(0.0218)
Non ICT Services		-0.0148	-0.0107
		(0.0225)	(0.0228)
Non ICT Other		0.00226	0.00860
		(0.0296)	(0.0302)
Non ICT Manufacturing		-0.0485**	-0.0450**
		(0.0194)	(0.0197)
E-banking	-0.0314	-0.0336	-0.0368*
	(0.0216)	(0.0218)	(0.0222)
E-training	0.0327**	0.0326**	0.0329**
	(0.0138)	(0.0138)	(0.0139)
Rest Marmara			-0.0281
			(0.0201)
Aegean			0.0224
			(0.0219)
West and Central Anatolia			-0.0358*
			(0.0192)
Mediterranean			-0.0413*
			(0.0244)
Rest Anatolia			-0.0197
			(0.0258)
Observations	3,633	3,633	3,633

Appendix 9

A.9.1. Test results for mobile connection

VARIABLES	(1)	(2)	(3)
Firm size	0.0638***	0.0638***	0.124***
	(0.00626)	(0.00629)	(0.00710)
Export share	0.293**	0.614***	0.669***
	(0.144)	(0.156)	(0.167)
Export share square	-0.347	-0.762***	-0.873***
	(0.250)	(0.261)	(0.278)
Lnitial Software Investment per emp.	0.0236***	0.0233***	0.0178***
	(0.00362)	(0.00360)	(0.00403)
Foreign share	0.00246***	0.00230***	0.00326***
	(0.000352)	(0.000347)	(0.000411)
R&D	0.00249	0.00492	0.0221**
	(0.00749)	(0.00730)	(0.00884)
ICT Producing and Using Services		0.151***	0.0916***
		(0.0282)	(0.0289)
Non ICT Services		0.0970***	0.156***
		(0.0308)	(0.0324)
Non ICT Other		0.0488	-0.0209
		(0.0384)	(0.0381)
Non ICT Manufacturing		0.0279	0.00596
		(0.0253)	(0.0265)
E-banking	0.147***	0.144***	0.129***
	(0.0213)	(0.0214)	(0.0248)
E-training	0.160***	0.159***	0.133***
	(0.0158)	(0.0158)	(0.0171)
Rest Marmara			-0.0571**
			(0.0242)
Aegean			-0.103***
			(0.0237)
West and Central Anatolia			-0.0529**
			(0.0240)
Mediterranean			-0.174***
			(0.0255)
Rest Aantolia			-0.148***
			(0.0274)
Observations	3,633	3,633	3,633

Appendix 10

A10.1. Test results for other fixed connection

VARIABLES	(1)	(2)	(3)
Firm size	0.122***	0.124***	0.124***
	(0.00686)	(0.00702)	(0.00710)
Export share	0.365**	0.706***	0.669***
	(0.155)	(0.168)	(0.167)
Export share square	-0.427	-0.911***	-0.873***
	(0.270)	(0.280)	(0.278)
Initial Software Investment per emp.	0.0213***	0.0212***	0.0178***
	(0.00402)	(0.00400)	(0.00403)
Foreign share	0.00358***	0.00344***	0.00326***
	(0.000412)	(0.000411)	(0.000411)
R&D Personnel Exp.	0.0196**	0.0216**	0.0221**
	(0.00908)	(0.00893)	(0.00884)
ICT Producing and Using Services		0.0862***	0.0916***
		(0.0288)	(0.0289)
Non ICT Services		0.135***	0.156***
		(0.0317)	(0.0324)
Non ICT Other		-0.0255	-0.0209
		(0.0378)	(0.0381)
Non ICT Manufacturing		-0.0169	0.00596
		(0.0260)	(0.0265)
E-banking	0.151***	0.146***	0.129***
	(0.0236)	(0.0240)	(0.0248)
E-training	0.131***	0.128***	0.133***
	(0.0170)	(0.0171)	(0.0171)
Rest Marmara			-0.0571**
			(0.0242)
Aegean			-0.103***
			(0.0237)
West and Central Anatolia			-0.0529**
			(0.0240)
Mediterranean			-0.174***
			(0.0255)
Rest Anatolia			-0.148***
			(0.0274)
Observations	3,633	3,633	3,633

Appendix 11

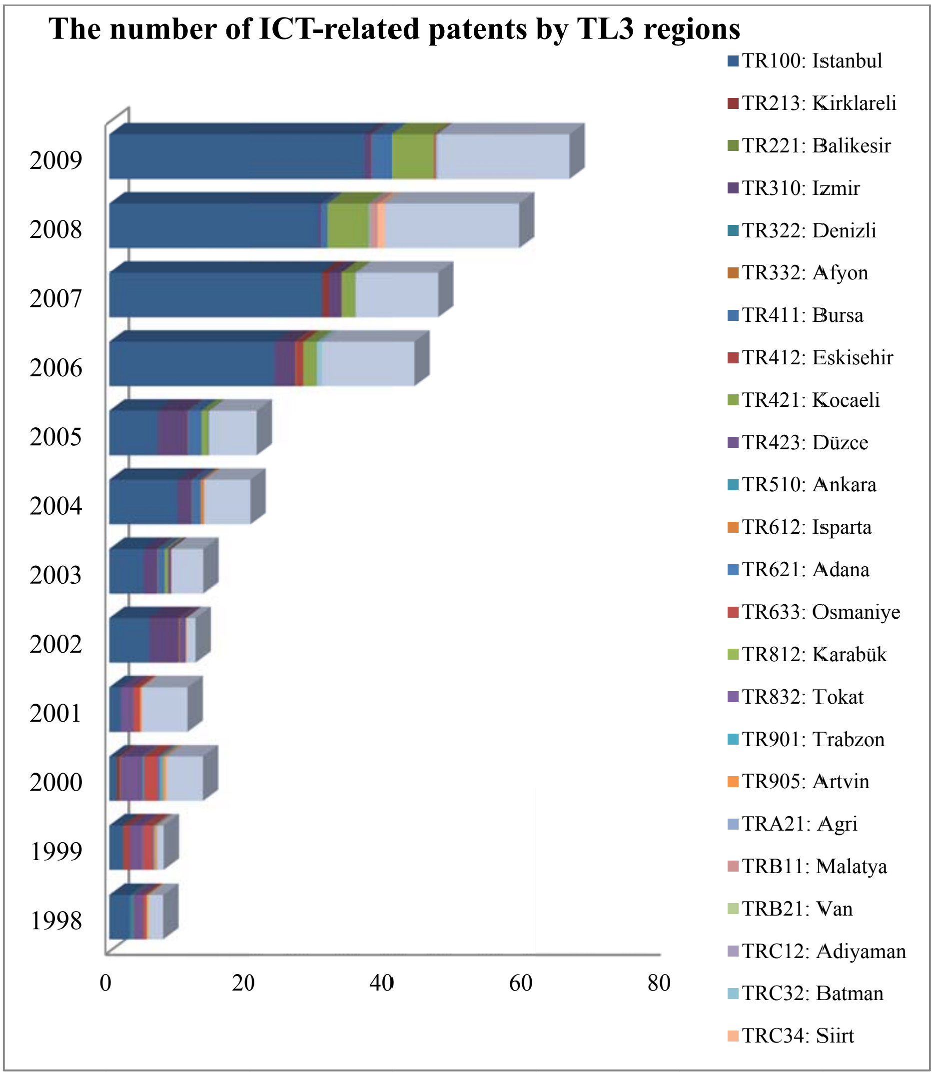

Figure A.11.1. The number of ICT-related patents by TL3 regions[42] (1998-2009)

Source: OECD(2011)

[42] According to OECD Regions at a Glance Report (2011), regions are classified in terms of territorial levels. For instance the higher level(Territorial level 2-TL2) consists of 335 large regions while lower level (Territorial level 3-TL3) is composed of 1681 small regions. All regions are defined mostly based on administrative borders.

Appendix 12

A.12.1. Descriptive statistics

Years	Variable	Obs	Mean	Std. Dev.	Min	Max
2003	Q	1696	14.69	1.68	6.15	20.75
	C	1696	12.84	2.00	2.29	19.33
	L	1696	4.68	1.14	2.40	8.99
	R	1696	15.43	1.74	8.11	22.76
	E	1696	12.20	1.93	3.09	18.76
	Software	1696	8.86	1.78	2.40	15.14
	Export	1696	0.25	0.31	0.00	1.00
	Outsourcing	1696	0.04	0.09	0.00	0.63
	R&D	1696	0.25	0.43	0.00	1.00
2004	Q	2106	16.02	1.53	9.75	22.84
	C	2106	13.42	1.80	7.10	20.01
	L	2106	4.63	1.10	2.64	9.04
	R	2106	15.49	1.61	9.12	22.73
	E	2106	12.07	1.86	3.01	18.49
	Software	2106	9.02	1.77	0.00	15.47
	Export	2106	0.20	0.26	0.00	1.00
	Outsourcing	2106	0.04	0.08	0.00	0.59
	R&D	2106	0.21	0.40	0.00	1.00
2005	Q	1762	16.20	1.53	11.99	22.88
	C	1762	13.93	1.78	6.05	20.41
	L	1762	4.76	1.13	2.40	9.10
	R	1762	12.37	1.79	4.53	18.82
	E	1762	12.42	1.88	3.46	18.61
	Software	1762	8.91	1.81	3.75	15.77
	Export	1762	0.19	0.26	0.00	0.99
	Outsourcing	1762	0.04	0.08	0.00	0.71
	R&D	1762	0.22	0.41	0.00	1.00
2006	Q	1500	14.77	1.55	8.02	20.53
	C	1520	14.19	1.70	8.31	20.38
	L	1520	4.79	1.12	2.40	8.83
	R	1520	15.78	1.61	9.92	21.84
	E	1520	12.60	1.70	7.83	18.54
	Software	1520	9.45	1.83	1.61	17.61
	Export	1520	0.19	0.24	0.00	0.99
	Outsourcing	1520	0.00	0.01	0.00	0.15
	R&D	1520	0.17	0.38	0.00	1.00

A.12.1. Continued

2007	Q	1366	16.40	1.56	10.50	22.92
	C	1366	14.41	1.71	6.17	20.79
	L	1366	4.86	1.16	2.48	9.09
	R	1366	15.82	1.66	9.44	22.82
	E	1366	12.71	1.73	8.46	18.61
	Software	1366	9.38	1.86	4.33	16.28
	Export	1366	0.17	0.23	0.00	0.99
	Outsourcing	1366	0.01	0.03	0.00	0.41
	R&D	1366	0.19	0.39	0.00	1.00

Appendix 13

Turkish Summary

1. Giriş

Bilgi ve iletişim teknolojileri (BİT)'in benimsenmesi ve bundan sağlanan kazançlar BİT üzerine yapılan çalışmaların odağını oluşturmaktadır. Türkiye gibi gelişmekte olan ülkelerin çoğu, bu ülkelerde internet kullanıcılarının sayısının artmasına rağmen, henüz teknoloji üreticisi olma düzeyine erişememişlerdir. Bu nedenle, teknoloji üretimi ile ilgili bir politika geliştirmeden önce bu ülkelerde teknoloji kullanımı düzeyini belirlemek gereklidir. Bu tezde teknoloji kullanım düzeyi, teknolojilerin özelliklerine göre 3 farklı seviyede ölçülmüştür.Birinci seviyede birbirleriyle tamamlayıcılık özelliği gösteren teknolojilerden oluşan teknoloji sahipliği indeksi oluşturulmuştur. İkinci seviyede ise ERP ve CRM gibi spesifik teknolojilerin kullanımı ölçülmüştür. Üçüncü seviyede ise darbant ve genişbant teknoloji gibi basit ve daha karmaşık teknolojilerin kullanım düzeyleri ölçülmektedir.

Bu tezde ayrıca Türkiye'de firma düzeyinde BİT kullanımı firma düzeyinde hem kesit analizi hem de panel veri analizi kullanılarak incelenmiştir. Kesit analizinde firma büyüklüğü, ihracat yapısı, Ar-Ge personeli harcaması, yazılım başlangıç yatırımı, yabancı sermaye payı, bölge ve sanayi değişkenleri için kukla değişkenler gibi firmaya özgü değişkenlerin BİT'in benimsenmesi üzerine etkileri incelenmiştir. Panel veri analizinde, bağımlı değişkenler ile açıklayıcı değişkenler arasındaki zaman farkı dört yıla çıkarılmaktadır Bu şekilde BİT kullanımının firma düzeyindeki belirleyicilerinin hem kısa vadeli hem de uzun vadeli etkilerinin gözlemlenmesi mümkün olmaktadır. Bu tezde ayrıca yazılım yatırımlarının firma etkinliği üzerine etkisi araştırılmaktadır Buna göre. 2003-2007 döneminde Türkiye'de yazılım yatırım yapan firma sayısı azalmıştır. Öte yandan, halihazırda yazılım yatırımı yapan firmaların bu yatırımlarında artış meydana gelmiştir. Bu tezde yazılım yatırımlarında gözlenen bu artışın verimlilik artışına neden olup olmadığı incelenmiştir.

BİT ‘in benimsenmesi hususunda, benimseme hızı ve ağ etkileri en önemli faktörlerdir. Bir teknolojinin benimseme hızı o teknolojinin ortaya çıktığı toplumsal sistemin üyeleri arasında ne kadar hızlı yayıldığı ile ilişkilidir. Ağ etkisi ise o teknolojinin kullanımı neticesinde sağlanan yararın artışı ile ilintilidir.

Herhangi bir teknolojinin benimsenme hızı o teknolojinin kendi özellikleriyle yakından ilgilidir. Bazı teknolojiler hemen ortaya çıktıktan sonra benimsenir iken bazılarının benimsenme hızı oldukça düşüktür. Eğer teknoloji ortaya çıktığı sosyal sistemin özelliklerine benzemiyorsa tamamen farklı ihtiyaçlara cevap veriyorsa bu durumda benimse hızının düşük olması kaçınılmazdır. Rosenberg (1972) teknolojinin benimsenmesi konusunda çevresel ve/veya kurumsal özelliklerin etkili olabileceğini öne sürmüştür. Örneğin yüksek teknoloji ürünleri üzerine konulan ağır vergiler bu teknolojilere yönelebilecek yatırımı engelleyen en önemli faktörlerden biridir.

BİT benimsenmesi ile ilgili ikinci faktör kabul oranıdır. Bir teknolojinin toplumsal sistemin üyeleri tarafından kabul edilme oranı o teknolojinin ortaya çıkardığı fayda ve maliyetlerle de yakından ilintilidir (Hall and Khan, 2003). Teknolojinin öngördüğü faydalar da firmaya özgü birtakım faktörler ile birlikte çevresel faktörlere bağlıdır. Örneğin herhangi bir firmada nitelikli işgücünün bulunması o teknolojinin benimsenmesinde rol oynayan en önemli faktörlerden biridir. Eğer teknoloji öğrenmesi zor olan ya da zaman gerektiren yeni beceriler gerektiriyorsa bu durumda benimseme hızı yavaşlayabilir. Çevresel faktörlerden biri olarak firmanın faaliyet gösterdiği sektörün, teknik kapasitesi benimseme hızı açısından önemlidir (Rosenberg, 1972).

Yeni bir teknolojinin sağladığı faydaların artmasında zaman faktörünün de büyük etkisi vardır. Buna göre, teknoloji sayesinde yaşanılan verimlilik artışı teknolojinin benimsenmesini izleyen aşamalarda daha yüksektir. Türkiye'deki firmalarda bilgisayarların yaygın kullanımı ile kablosuz yerel ağ (WLAN) ve kurumsal kaynak planlaması (ERP) gibi teknolojilerin kullanımı artmıştır. Buna göre firmaların WLAN kullanım payı 2007'den 2009'a kadar yüzde 10 oranında artmıştır. Aynı dönemde, ERP kullanıcıları payı yüzde 20 oranında artmıştır(TÜİK, 2007-2009).

BİT kabulü için üçüncü önemli faktör ağ etkisidir. Doğrudan ve dolaylı olmak üzere iki tür ağ etkisi bulunmaktadır. Doğrudan ağ etkisi, faydası varolan teknolojinin kullanımı ile artan etkidir. Dolaylı ağ etkisinde ise teknolojinin faydası onu tamamlayıcı başka bir teknolojinin varlığında ortaya çıkmaktadır. Amitt ve Zott (2001)'a göre birbirini tamamlayıcı özellikleri olan teknolojilerin varlığı firma faaliyetlerinin daha etkin bir şekilde yürütülmesini sağlamaktadır. Bu tezde, teknolojinin dolaylı ağ etkisi birbirini tamamlayıcı özelliklere sahip LAN, WLAN, intranet ve extranet gibi teknolojilerin oluşturduğu teknoloji sahipliği endeksi oluşturularak incelenmiştir. Buna göre intranet ve ekstranet teknolojileri birbirini tamamlayıcı özelliklere sahiptir. Ekstranet teknolojisi firmanın dış piyasalarla olan ilişkilerini yönetirken, intranet teknolojisi firma içindeki faaliyetlerin düzenlenmesinde rol oynar. Bu teknolojilerin her ikisini de kullanan firmalar, bu teknolojilerden herhangi birini kullananlara göre daha avantajlı durumda bulunmaktadırlar.

Bu tez iki ana bölümden oluşmaktadır. İlk bölümde Türkiye'deki firmaların BİT'i benimsemeleri sürecinde firmaya özgü faktörlerin etkisi analiz edilmektedir. İkinci bölümde ise yazılım yatırımının firma verimliliğine etkisi incelenmektedir. Çalışmanın ilk bölümünde, BİT'in benimsenmesi konusu iki farklı düzeyde değerlendirilmektedir. İlk düzeyde, teknoloji benimseme kararı zaman içinde bir noktada verilen karar olarak kabul edilir, bu nedenle firma düzeyinde kesit analizi yapılmaktadır. Bu analiz 2009 yılına ait Girişimlerde Bilişim Teknolojileri Kullanma Anketi verileri ile 2007 yılı Yapısal İş İstatistikleri Anketi'nin birleştirilmesiyle gerçekleştirilmektedir. Böylece teknoloji benimseme kararını etkileyen firma düzeyindeki verilerin teknoloji benimseme kararı üzerinde gecikmeli etkileri olduğu varsayılmaktadır.

İkinci aşamada, teknoloji benimseme kararı bir yayılım sürecini ifade eder. Bu nedenle bu aşamada panel veri analizi kullanılmaktadır. İlk hipotez "paneli etkisi" ile ilgilidir. Yeni bir fikrin tanıtılması ve yayılması için hatırısayılır bir zaman farkı gereklidir (Rogers ve Shoemaker, 1971). Teknolojinin yayılma süreci; farkındalık, ilgi, değerlendirme, ve deneme gibi çeşitli aşamalardan oluşmaktadır. Farkındalık aşamasında, firma teknolojinin varlığından haberdar olur. Daha sonraki aşamada bu teknolojiye karşı ilgi geliştirir. Değerlendirme aşamasında ise, firma bu teknolojiyi benimsemenin fayda ve maliyetlerini değerlendirir. Deneme aşamasında firma yeni teknolojiyi küçük ölçekte kullanılır. Bu nedenle, bir firmada teknoloji hemen kabul edilmeyebilir ve ileriki bir tarihe kadar benimseme kararı ertelenebilir. Teknolojinin yayılım süreciyle ilgili ikinci hipotez firmaya özgü değişkenlerin gecikmeli etkileri ile ilgilidir. Kesit analizi BİT'in benimsenmesi ve benimseme davranışını belirleyen faktörler arasında iki yıllık bir gecikme olduğu hipotezine dayanmaktadır. Panel veri analizi çerçevesinde ise firmaya özgü faktörlerin BİT üzerindeki etkileri için zaman farkı dört yıla kadar uzatılmaktadır. Böylece firmaya özgü değişkenlerin etkilerinin uzun vadede etkili olup olmadığı test edilmiş olur.

Tezin ikinci bölümünde Türkiye'de 2003-2007 yılları arasında yazılım yatırımı yapan imalat sanayi firmalarının firma verimliliği incelenmektedir. Son yıllarda maddi olan yatırımların payı Almanya, Hollanda, Belçika, İtalya ve İspanya gibi AB ülkeleri için azalırken, maddi olmayan yatırım payı artmıştır. Maddi olmayan yatırımlar çeşitli şekillerde sınıflandırılabilir. Corrado ve Van Ark (2009)'un geliştirdiği sınıflandırmaya göre, maddi olmayan yatırımlar bilimsel ve yaratıcı özelliği ve ekonomik yetkinlikleri içermektedir. Yazılım bu özellikleri sağlayan ve maddi olmayan yatırım bileşenidir. Türkiye'de, 2003-2007 yılları arasında da yazılım yoğunluğunda bir artış olmuştur. Tezin bu bölümünde yazılım yatırımlarındaki bu artışın firma verimliliği üzerine etkisi incelenecektir.

Bu tez şu şekilde düzenlenmiştir. Giriş bölümünün ardından, tezin ikinci bölümünde Türkiye'de bilgi ve iletişim teknolojileri kullanımı üzerine veri toplama faaliyetleri ile bu faaliyetlerin altyapısını oluşturan politika metinleri incelenmektedir. Üçüncü bölümde bilgi ve iletişim teknolojilerinin benimsenmesi ile ilgili teorik ve ampirik literatür irdelenmiştir. Bu bölümde ek olarak Türkiye'de bulunan firmaların BİT kullanımı firma düzeyinde veri kullanılarak incelenmiştir. Dördüncü bölümde yazılım yatırımlarının firma verimliliği üzerindeki etkisi mikro veri kullanılarak incelenmiştir. Son bölümde tezin genel bulguları tartışılmakta ve bu sonuçların ışığında bir dizi politika önerisi sunulmaktadır.

Bölüm 2 Türkiye'de BİT konusundaki politika metinlerini ve BİT ile ilgili toplanan verileri tarihsel olarak incelemektedir. 1971 yılında yapılan ilk anket sonuçlarına göre, bilgisayar kullanımı finans ve sigorta gibi hizmet sektöründe en yüksek düzeydeydi. Daha sonraki yıllarda (1980-1982), bilişim ile ilgili hizmet sağlayan firmaların sayısı yüzde 50 oranında artmıştır. İlgili dönemde kamu sektörü, bilişim hizmetleri kullanımında en önemli paya sahipken bu hizmetlerin pazarlanmasıyla ilgili herhangi bir strateji bulunmamaktaydı. BİT kullanımı ile ilgili ilk Hanehalkı Araştırması 1997 yılında yapılmıştır. Bu anketin sonuçları gelir ve bilgisayar sahipliği arasında pozitif bir ilişki olduğunu ortaya koymuştur. Masaüstü bilgisayar sahipliği yüksek gelir gruplarında düşük gelir gruplarına göre daha yüksektir. Düşük gelir gruplarında, telefon kullanıcı sayısı bilgisayar kullanıcı sayısından daha yüksektir. Hanehalkı Bilişim Teknolojileri Kullanım Araştırması (2005) sonuçlarına göre kentsel ve kırsal haneler arasında masaüstü ve dizüstü bilgisayarların mülkiyet dağılımında uçurum bulunmaktadır. Aynı fark cep telefonu sahipliğine gelince ortadan kalkmaktadır.

Bölüm 3 teori ve ampirik literatür sunarak BİT'in benimsemesini etkileyen firmaya özgü belirleyicilerin ayrıntılarına yer vermektedir. BİT'in benimsenmesiyle ilgili klasik ve modern benimseme teorileri olmak üzere iki tür yaklaşım bulunmaktadır. Klasik benimseme teorisi, teknoloji benimseme davranışının zaman içinde S şeklinde eğri biçiminde ilerlediğini varsaymaktadır. Bu eğri kümülatif benimseme oranı ile zaman arasındaki ilişkiyi gösteren lojistik bir dağılıma sahiptir. Büyüme başlangıç aşamasında eğri üzerinde üstel durumdadır. Bu eğri üzerinde doygunluk noktasına ulaşıldığında büyüme yavaşlar. Klasik benimseme teorisi içerisinde bu eğrinin şeklini belirleyen içsel ve dışsal etki modelleri olmak üzere iki tür model yer almaktadır.

İçsel etki modelinde teknolojinin benimsenmesi kişiler arası etkileşim neticesinde gerçekleşir. Bu özellik, teknolojiyi daha önce benimseyen kullanıcılarla potansiyel kullanıcılar arasındaki etkileşimi zorunlu kılmaktadır. Dışsal etki modellerine göre ise teknolojinin yayılımı toplumsal sistemin dışındaki etkenlere bağlı olarak meydana gelir. Dışsal etki modelinde, bir önceki modelin tersine teknolojiyi daha önce benimseyenlerle potansiyel kullanıcılar arasındaki etkileşime izin verilmez.
İçsel ve dışsal etki modeline ek olarak çok kademeli difüzyon modeli bulunmaktadır. Bu difüzyon modeli; tamamlayıcılık, bağımsızlık, tesadüfilik, ve ikame edilebilirlik gibi özelliklerden oluşmaktadır. Bağımsızlık farklı işlevleri olan teknolojilerin birbirinden bağımsız olduğunu varsaymaktadır. Tamamlayıcılık özelliğine göre ise farklı işlevleri bulunan teknolojilerin birbirini tamamlayıcı özelliklere sahip olduğu kabul edilmektedir. Bir başka deyişle bir yeniliğin benimsenmesi diğer yeniliğin benimsenmesini artırır. Bu nedenle, teknolojinin farklı işlevleri birbirini

tamamlayıcı olabilir. Buna ek olarak, bir teknoloji benimsenmesi diğer teknolojinin varlığına bağlı olabilir. Bu teknolojinin tesadüfilik özelliğine dayanmaktadır. Bazı durumlarda ise bir teknolojinin kullanılması diğer teknolojiye olan talebi düşürebilir. Bu da teknolojinin ikame etkisi olarak isimlendirilmektedir.

Çağdaş benimseme teorisi, klasik benimseme teorisinin aksine firmaya özgü faktörlerin varlığı ile ilgilidir. Çağdaş benimseme teorisi üç farklı türde anılmaktadır. Bunlar; sıralama, epidemik, ve stok modelleridir. Sıralama modelleri teknolojinin sağladığı getiriler açısından sıralanmasına dayanmaktadır. Bu modelde kullanıcı özellikleri ön plana çıkmaktadır. Örneğin, firmanın büyüklüğü teknolojinin erken kabulünde belirleyici bir rol oynar. Epidemik model öğrenmeyi içerir. Bu modelde bölge ve sanayi gibi çevresel faktörler kullanılmaktadır. Stok ve sipariş modelleri oyun teorisi yaklaşımına dayanmaktadır. Buna göre firmanın teknoloji benimseme kararı, o teknolojinin karlılığı ile doğru orantılıdır.Bu model, firma karlılığı üzerinde elimizde veri olmadığından bu tezde uygulanmamaktadır

Bu tezde, firmaların teknoloji benimseme davranışı; teknoloji sahipliği, kurumsal kaynak planlaması (ERP) ve müşteri kaynak yönetimi (CRM) kullanımı ile dar ve geniş bant teknolojilerin kullanımından oluşmaktadır: Teknoloji sahipliği modeli aşağıdaki göstergeler ile ölçülür. Buna göre teknoloji sahipliği modeli Yerel Alan Ağı (LAN), Kablosuz Yerel Alan Ağı (WLAN), Intranet, ve Ekstaranet teknolojilerinden oluşmaktadır. LAN, sınırlı bir alanda sabit noktalar arasında veri alışverişi için kullanılmaktadır. WLAN, daha geniş alanda kullanılan ve kullanıcı için hareketlilik sağlayan bir teknolojidir. Bu teknolojinin kullanımı dizüstü bilgisayarların ortaya çıkmasıyla artmıştır. Intranet firma içi bilgi paylaşımı için kullanılmaktadır. Bu sistem gizlilik esasına göre çalışır, bir başka deyişle bu sistemde sadece firma içerisindeki bilgilerin dolaşımına izin verilmiştir. Ekstranet intranetin güvenli bir uzantısı olmakla birlikte tamamen farklı bir işleve sahiptir. Bu sistem kullanıcıların stratejik ortakları ve müşterileri ile iletişim kurmasını sağlar. Çalışmanın ilk bölümünde, teknoloji sahipliği modeli bu teknolojilerden oluşturduğumuz bir endeksle ölçülmektedir. Teknoloji sahipliği endeksi, yukarıda sayılan teknolojilerin birbirini tamamlayıcı özelliğe sahip olduğu varsayımına dayanarak oluşturulmaktadır.

Teknoloji sahipliği modeline ek olarak bu tezde, ERP ve CRM gibi spesifik teknolojilerin kullanımı da araştırılmaktadır. ERP tek bir bilgisayar sistemi (Nelson ve Somers, 2001) içinde firmanın farklı işlevlerinin entegre edildiği bir sistemdir. Bu sistem sayesinde firma içi ve firma dışı bilgiler yönetilebilir hale gelmiştir. Yüksek kurulum maliyetleri nedeniyle, büyük firmaların ERP sistemi için yatırım yapması daha kolaydır.

CRM sistemi müşteriler ve tedarikçiler arasındaki ilişkiyi yönetmek için kullanılır. Bu tezde ayrıca bağlantı türleri de incelenmiştir. Bağlantı türlerini geleneksel modem veya Tümleşik Hizmetler Dijital Ağ bağlantısı (ISDN), Asimetrik Sayısal Abone Hattı (ADSL), diğer sabit internet bağlantısı ve mobil bağlantısı olarak gruplandırmak mümkündür. Bağlantı türlerini incelememizin amacı firmaların eski ve yeni teknolojileri kullanmak açısından farklı olup olmadıklarını araştırmaktır. Geleneksel modem veya ISDN modem kısıtlı bağlantı sağlar, ve düşük bağlantı hızı nedeniyle "dar" bağlantı olarak isimlendirilmektedir. ADSL genişbant bağlantısının tipik bir örneğidir ve ISDN bağlantısına göre daha yüksek hızda veri iletimine izin vermektedir. ADSL, ISDN sistemi üzerine kurulmuş olmasına rağmen, farklı çalışmaktadır. ADSL çok çeşitli internet uygulamaları için kullanılır. Indirme hızı, internette daha kolay sörf edebilme imkanı ADSL bağlantısını kullanıcılar için cazip hale getirmektedir. Yükleme hızı, daha hızlı olduğu için de asimetrik olarak adlandırılmaktadır. Diğer sabit internet bağlantısı Kablo Modem Bağlantısı, Yüksek Kapasiteli Kiralık Hat, Sabit Kablosuz

İnternet Erişimi (FWA) ve Wireless Fidelity (Wi-Fi)'yi içerir. Bu bağlantı türlerinin her biri için ankette herhangi bir bilgi bulunmamaktadır.

Bölüm 3'de firmaların BİT benimsemesinin belirleyicileri ampirik olarak incelenmektedir. Sıralama ve epidemik modelleri; firma büyüklüğü, yabancı sermaye sahipliği, ihracat payı, Ar-Ge personeli harcamaları, bilgi ve iletişim teknolojileri kullanım amaçları ve örgütsel atmosfer gibi firmaya özgü değişkenler teknoloji benimsemesinin belirleyicileri olarak kullanılmaktadır. Büyük firmalar kaynaklara erişim ve yeni teknolojinin benimsenmesi için gerekli altyapıya sahip olma açısından küçük firmalara göre daha avantajlı konumdadır. Schumpeteryan görüşe dayanan varsayımlarında Cohen ve Levin (1989), firma büyüklüğü ve yenilikçi faaliyetler arasındaki bağlantıyı ele alırken büyük firmaların küçük firmalara göre örgütsel beceriler açısından daha yenilikçi olduklarını savunmuşlardır.

Buna ek olarak, özellikle bilgi ürünleri için, ürün farklılaştırması rekabet avantajı sağlama açısından çok önemli bir rol oynamakta ve "en iyi" ürünleri üreten büyük firmalar küçük rakipleri üzerinde maliyet avantajına sahip olmaktadırlar (Shapiro ve Varian, 1999, s. 25). Rothwell (1972) en iyi ürünün başarı nedenlerini açıklarken ürün geliştirme aşamasında akademik dünya ile bağlantı halinde olmanın, ürün geliştirme için uygun bir yönetim stratejisi uygulamanın, etkin pazarlama stratejileri kullanmanın, kullanıcı ihtiyaçlarının karşılanmasının ve firmada stratejik bir rol oynayan bireylerin varlığının önemini vurgulamaktadır. Firmaların üretim süreci içerisinde tüm bu adımların organize edilmesi ürün farklılaştırması açısından gereklidir.

BİT benimsemesinde yabancı payının rolü büyük ölçüde ekonomik kalkınma açısından incelenmiştir. Gelişmekte olan ülkelerde, yabancı sermayenin varlığı firmaların yeni beceriler öğrenmesine yardımcı olmaktadır. Ancak, dış kaynaklı faaliyetler teknolojik uzmanlık gerektirmeyen faaliyetleri de içeriyorsa yabancı sermaye gittiği ülkeye herhangi bir avantaj sağlamaz. Ek olarak iki ülke arasında nitelikli işgücü maliyeti açısından büyük farklılıklar varsa, yabancı firmalar daha ucuz olana yatırım yapmayı tercih eder. Yabancı sermaye yatırımı aracılığıyla gelişmekte olan ülkelerde birtakım becerilerin gelişmesi bu ülkelerde faaliyet gösteren firmaların altyapısına bağlıdır. Ayrıca, gelişmekte olan ülkelerdeki siyasi ortam da yabancı firmaların yatırım kararlarında önemli bir rol oynar. Örneğin, yabancı sermaye üzerinde vergi indirimi sağlanması çokuluslu firmalar için cazibe unsurlarını oluşturmaktadır.

İhracat faaliyetleri ile BİT benimsemesi arasındaki ilişkiyi analiz eden çalışmalar ihracat yapan firmaların dış bağlantılar yoluyla yeni teknolojileri daha hızlı benimsediklerini ortaya koymuştur. Bunun nedenleri arasında uluslararası pazarda rekabet baskısı yer almaktadır. Ek olarak ihracata konu olan faaliyetler bir teknolojinin benimsenmesini gerekli kılabilir.

BİT'in benimsenmesi ile ilgili önemli bir diğer husus beşeri sermayenin etkisi söz konusu olduğunda, kullanıcının sahip olduğu bilgi ve eğitim düzeyinin önem kazanmasıdır. Buna göre bir firmada yüksek vasıflı işgücünün bulunması potansiyel benimseyenler üzerinde olumlu bir etki meydana getirmektedir.

Literatürde, bilgi ve iletişim teknolojileri kullanım amaçları girdi maliyetlerini azaltma veya kaliteyi iyileştirmeye dayalı olabilir(Arvanitis ve Hollenstein 2001 Hollenstein, 2004). Bu tezde bu amaçları temsil etmek üzere e-bankacılık ve e-eğitim gibi iki gösterge kullanılmaktadır. Girişimlerde Bilişim Teknolojileri Kullanımı Anketi (2009)'a göre, e-bankacılık faaliyetleri firma ile finansal kuruluşlar arasında otomatik veri değişimi için internetin kullanılmasını ifade eder. E-eğitim ise eğitim faaliyetlerine çalışanların web üzerinden katılımını ifade eder. Internet üzerinden yapılan bankacılık işlemleri firmanın işlem maliyetlerini azaltan bir unsurdur.

Örgütsel çevre teknoloji kabulünü etkileyen bir başka faktördür. Bu tezde, firmanın faaliyet gösterdiği sanayi kolu ve bölgesel konumu çevresel faktörler olarak kullanılmıştır. Bu bağlamda, firmalar arası heterojenliği sağlamak amacıyla bölge ve sanayi kukla değişken olarak kullanılmıştır. Sanayi değişkeni O'Mahony ve Van Ark (2003)'ın sanayi sınıflandırması kullanılarak oluşturulmuştur. Buna göre, sanayi değişkeni BİT kullanımı ve üretimi açısından sınıflandırılır. Bu kategoriye girmeyen tarım ve inşaat sektörleri 'diğer' başlığı altında toplanmıştır. Bu nedenle, teknolojinin benimsenmesi davranışı sanayi genelinde farklı varsayılmaktadır.

Firmanın coğrafi konumu da firmalar arasında BİT kullanımı konusunda farklılaşmayı sağlayan bir unsur olarak kullanılabilir. TÜİK (2008a) rehberliğinde, bölge değişkeni Türkiye'deki 12 bölge esas alınarak oluşturulmuştur. Ancak bazı bölgelerdeki gözlem eksikliği nedeniyle 12 grup 6 gruba indirgenmiştir. Hipotezimize göre BİT kullanımı bölgeler arasında değişkenlik göstermektedir. Bazı bölgelerde yazılım şirketlerinin sayısı yüksek olduğu için, bilgi ve iletişim teknolojileri yayılma oranı daha yüksektir. Bu nedenle, vasıflı işçilerin yüksek olduğu bir bölgede daha yüksek oranda BİT kullanımı gözlemlenebilir. Örneğin, Doğu ve Güney-Doğu Anadolu gibi bilgi kanalları, girişimcilik, ve işgücü becerileri açısından dezavantajlı olan bölgelerde BİT kullanımı daha düşük olabilir. Bunun bir göstergesi olarak 1998-2009 yılları arasında BİT konusunda alınmış patent sayısı dikkate alındığında iki gözlem dikakt çekmektedir.Birincisi ilgili dönemde BİT ile ilgili patent sayısındaki artıştır. İkincisi ise İstanbul'da patent payının ilgili dönemde hızlı bir şekilde artmış olmasıdır. Bu sonuç, ülkede BİT konusunda alınan patentlerin dengesiz dağılımı ortaya koymaktadır

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Bölüm 4 firma verimliliği üzerindeki yazılım yatırım etkisini incelemektedir. Buna göre 2003-2007 döneminde yazılım yatırımlarıyla ilgili iki nokta gözlemlenmiştir. İlk olarak, yazılım yatırımı yapan firma sayısı bu dönemde azalmıştır. İkinci olarak, yazılım yatırım yoğunluğu o yıllarda artmıştır. Diğer bir deyişle, yazılım yoğun firmalar daha fazla yazılım yatırımı yapar hale gelmiştir. Bu tez, yazılım yatırımı yoğunluğundaki bu artışın Türk imalat firmaları için yüksek verimliliğe neden olup olmadığını açıklamayı amaçlamaktadır.

Zamanla değişen stokastik sınır modeli firmanın verimlilik belirleyicilerini açıklamak için kullanılır. Alternatif bir yaklaşım olan Veri Zarflama Analizi (DEA)'nde stokastik sınır yaklaşımından farklı olarak teknik verimsizlik ve istatistiksel hata biribirinden ayırt edilemez.

Bölüm 5'te temel sonuçlara ve politika önerilerine yer verilmektedir. Kesit analizi ve panel veri analizinin sonuçları dikkate alınarak firmaya özgü değişkenlerin BİT benimsenmesi üzerinde kısa vadeli ve uzun vadeli etkilerinden söz etmek mümkündür. Kesit analizinde bağımlı değişken ile bağımsız değişken arasında iki yıllık bir zaman aralığı kullanılır. Bu aralık panel veri analizine gelindiğinde 4 yıla çıkmaktadır

2.Veri ve Yöntem

Bu bölüm, veri kaynakları ve veri temizleme işlemlerini incelemektedir. Bu tezde iki tür veri kaynağı kullanılmıştır. Bunlar; "Girişimlerde Bilgi ve İletişim Teknolojileri Kullanımı" ve "Yıllık Yapısal İş İstatistikleri"dir.

Bu tezde, firma düzeyinde bilgi ve iletişim teknolojilerinin benimsenmesi kesit ve panel veri yöntemleri kullanılarak analiz edilmiştir. Kesit analizinde, 2009 yılına ait Girişimlerde Bilişim Teknolojileri Anketi verileri ile 2007 yılına ait Yıllık Yapısal İş İstatistikleri Anketi kullanılmıştır. Panel veri analizinde ise Yıllık Yapısal İş İstatistikleri Anketi 2003-2007 ile Girişimlerde Bilişim Teknolojileri Kullanımı 2007-2011 Anketi verileri kullanılmıştır.

Firma etkinliği analizi için ise Yıllık Yapısal İş İstatistikleri (2003-2007) Anketi kullanılmıştır. Bu anketlerde her firma için satış, gelir ve maliyetler hakkında ayrıntılı bilgi bulunmaktadır. Veri setini oluşturmak için öncelikle ayrı bir set olarak sunulan 2007 yılı anketi ile 2003-2006 dönemine ait veriler ortak kimlik numaralarını içeren bir anahtar yardımıyla birleştirilmiştir. Gözlemler silindikten sonra, her yıl için 17131 gözlem kalmıştır. Hizmet sektöründe verimlilik ölçümü imalat sanayi sektörlerinden oldukça farklı olduğu için, sadece imalat sanayi sektöründeki firmalar bu teze dahil edilmiştir. Bu veri kümesi içinde imalat sanayindeki firmaların sayısı 45900'dür.

Değişkenleri oluşturmak için veri kümesinden ilgisiz gözlemler temizlenmiştir. Bu tezde, imalat sanayi gelirleri değişkenine ait sıfır değerleri bulunmaktadır. Bu durum firmaların herhangi bir üretim faaliyeti yapmadığını göstermektedir. Bu nedenle, sıfır değerine sahip gözlemler örneklemden silinmiştir. Aynı prosedür, emek verilerine de uygulanmıştır. TÜİK'in veri toplama metodolojisine göre, yalnızca 20'den fazla işçi çalıştıran firmalar tam sayım usulüne tabi tutulmuştur. Bu nedenle, 20'den az işçi çalıştıran firmalar veri setinden silinmiştir. Bu çalışmada, yalnızca yazılım yatırımı yapan firmalar dahil edilmiştir.

Ek olarak ihracat değişkeni için ihracat oranı 1'den fazla olan gözlemler örneklemden silinmiştir. Buna göre son örneklem büyüklüğü 8450 gözlem içermektedir.

3.Sonuçlar

Bu tezde bilgi ve iletişim teknolojileri hem benimseme davranışı hem de firma performansı açısından incelenmiştir. Benimseme davranışı firmaya özgü faktörlerin BİT benimsemesi üzerinde gecikmeli etkileri olduğu varsayımına dayanmaktadır. Bu tezde iki farklı zaman aralığı kullanarak optimal gecikme süresi hesaplanmaktadır. Ayrıca, bu tezde kesit ve panel veri analizi uygulanmıştır. Kesit analizinde, bağımlı değişken ve açıklayıcı değişkenler arasında iki yıllık bir gecikme bulunmaktadır. Bu etki kısa vadeli etkileri gösterir. Panel veri analizinde ise, zaman farkı uzun vadeli etkileri gösterir ve dört yıla kadar uzanmaktadır.

Buna göre bazı firmaya özgü faktörlerin sadece acil etkileri bulunmaktadır. İkincisi, firmaya özgü bazı faktörlerin hem acil hem de uzun vadeli etkileri vardır. Üçüncü olarak ise, bazı firmaya özgü faktörlerin kısa vadeli etkisi ne de uzun vadeli etkisi bulunmaktadır.

Panel veri fark alma yöntemiyle analiz edildiğinde hem rastgele etkiler hem de sabit etkiler için benzer sonuçlar vermektedir. Alternatif tahmin sonuçlarına bakıldığında, firma büyüklüğü ve e-eğitim benimsenmesi hem kısa hem de uzun vadede olumlu etkilere sahiptir. Buna göre firma büyüklüğü ile ölçülen ölçek etkileri firmanın benimseme kararı üzerinde olumlu etkilere sahiptir. Aynı etki e- eğitim değişkeni için de geçerlidir.

Ihracat payı firmanın ticarete olan açıklığını göstermektedir Bu tezde ihracat paylarının BİT benimsenmesi üzerindeki etkilerinin gecikmeli olduğu varsayılmaktadır. Firmalar ihracat faaliyeti yoluyla yabancı muadillerinden yeni teknoloji hakkında en güncel bilgiye sahip olabilirler. Kesit analizinin sonuçları da bu varsayımı desteklemektedir. İhracatın BİT üzerindeki olumlu etkisi panel veri analizi söz konusu olduğunda ise kaybolmaktadır.

Yazılım üzerine yapılan başlangıç yatırımı BİT benimsemesi üzerinde hem kısa vadeli hem de uzun vadeli etkileri kapsamaktadır. Uzun vadeli etkiler sadece GLLAMM işlemi için geçerlidir. Başlangıç yazılım yatırımının alternatif tahmin yöntemi sözkonusu olduğunda BİT benimsemesi üzerinde önemli bir etkisi yoktur. Ar-Ge personeli harcamaları, yabancı payı ve e-bankacılık değişkenleri de alternatif tahmin yöntemleri dikkate alındığında benimseme davranışı üzerinde anlamlı bir etkiye sahip değildir.

Sanayi için oluşturulmuş kukla değişkenleri sabit etkiler modelinde dahil edilmemiştir. Kesit analizinde ise BİT üreten veya kullanan olduğuna bakılmaksızın hizmet sektöründe faaliyet gösteriyor olmak benimseme davranışını olumlu etkilemektedir. Son olarak, bölgesel yığılmanın bir yıldan diğerine değişebileceği varsayılarak sabit etki tahmini için bölgesel yığılma değişkeni eklenmiştir. Bununla birlikte bu değişken, benimseme davranışı için anlamlı sonuçlar vermemiştir.

ERP ve CRM gibi özel teknolojilerin benimsenmesi üzerinde firmaya özgü faktörlerin etkilerine gelince, kısa vadeli etkileri ve uzun vadeli etkileri arasında farklılıklar vardır. Firmaya özgü faktörler uzun vadede ERP kabulü üzerinde anlamlı bir etki oluşturmaz. Kesit analizinde ise ERP teknolojisini benimseme ile firmaya özgü faktörler arasında iki yıllık bir gecikmenin anlamlı olduğu ortaya çıkmıştır. Panel veri analizinde tahminler ayrı ayrı imalat sektörleri ve hizmet sektörleri için tekrarlandığında, sadece firma büyüklüğünün imalat sektöründe ERP kabulü üzerinde olumlu etkisi bulunmaktadır. Bu sonuç, ölçek avantajlarının ERP benimsenmesi için önemli olduğunu göstermektedir. Diğer bir deyişle, firmanın büyüklüğü herhangi bir süre kısıtı olmaksızın benimseme davranışı üzerinde olumlu etkiye sahiptir. CRM'e gelince, firma büyüklüğünün imalat sektöründe bu teknolojinin benimsenmesi üzerinde olumsuz etkileri bulunmaktadır. Öte yandan, yabancı sermaye payının uzun vadede CRM kabulü üzerinde olumlu etkileri bulunmaktadır.

Eski ve yeni teknolojilerin benimsenmesi konusunda firmaya özgü faktörlerin etkilerine gelince, sadece yabancı payı, e-bankacılık, e-eğitim ve bazı bölge değişkenlerinin ISDN teknolojisinin benimsenmesi üzerinde olumlu etkisi bulunmaktadır. Uzun vadede ihracat payı ve Ar-Ge personeli harcamalarının imalat sanayi üzerinde olumlu etkileri bulunmaktadır. Hizmet sektöründe ise, ihracat payının ISDN teknolojisinin benimsenmesi üzerine olumsuz etkileri vardır. Çalışan başına yazılım yatırımlarının hizmet sektöründe ISDN kabulü üzerinde olumlu etkileri bulunmaktadır.

İhracat oranı imalat sanayi sektöründe mobil bağlantı kabulü üzerinde olumlu etkiye sahipken, diğer değişkenlerin uzun vadede mobil bağlantının benimsenmesi üzerinde herhangi önemli bir etkisi yoktur.

Bu tezde BİT benimsenmesi üç seviyede ölçülmektedir. İlki fonksiyonel olarak birbirini tamamlayıcı teknolojilerden oluşan teknoloji sahipliği endeksidir. İkincisi özel amaçlara hizmet eden ERP ve CRM teknolojilerinin kullanılmasıdır. Üçüncüsü ise eskiden yeniye doğru sıralanan dar bant ve genişbant teknolojilerinin kullanılmasıdır. Teknoloji sahipliği modeli göz önüne alındığında, firmaya özgü faktörlerin etkisi tamamlayıcı teknolojiler üzerinde daha fazladır. Firmaya özgü faktörlere bakıldığında büyük firmaların tamamlayıcı teknolojileri benimsemeleri daha muhtemeldir. Aynı etki ihracat payı, yabancı sermaye ve AR-GE personel gideri gibi diğer değişkenlerde de görülmektedir.

Bölge değişkenleri sözkonusu olduğunda İstanbul dışındaki bölgelerde faaliyet gösteren firmaların tamamlayıcı teknoloji kullanma olasılığı diğerlerine göre daha azdır. ERP ve CRM teknolojileri dikkate alındığında firma büyüklüğü, ihracat payı, yabancı payı, çalışan başına Ar-Ge, e-bankacılık ve e-eğitim faaliyetleri gibi firmaya özgü değişkenlerin etkisi ERP kullanıcıları için daha fazladır. Bölge ve sanayinin etkisine gelince, Marmara bölgesinde faaliyet gösteriyor olmak ERP kullanıcıları için daha avantajlı bir durumdur. Sanayinin etkisi söz konusu olduğunda, BİT üreten veya kullanan olup olmadığına bakılmaksızın hizmet sektöründe faaliyet gösteriyor olmak bu özel teknolojileri benimseme olasılığını artırmaktadır. ERP kullanımı imalat sanayinde daha sık görülmektedir. Tahmin sonuçları bu varsayımla uyum içindedir.

Darbant teknolojileri ve genişbant teknolojilerinin kullanımı göz önüne alındığında; firma büyüklüğü, ihracat payı, ihracat payının karesi ve Ar-Ge faaliyetleri darbant teknolojilerinin kullanımı ile ilgili önemli sonuçlar vermemektedir. Yabancı payı, e-bankacılık ve e-eğitim faaliyetleri ISDN teknolojisi kullanımı üzerinde olumlu etkileri bulunmaktadır. Firma büyüklüğü, ihracat payı, ihracat payının karesi, yabancı payı, e-bankacılık ve e-eğitim faaliyetleri mobil bağlantı ve diğer sabit bağlantının benimsenmesi üzerinde olumlu etkisi vardır.

Bu tezde ayrıca teknoloji sahipliği, ERP ve CRM teknolojileri kullanımı ve dar ve geniş bant teknolojileri kullanımı için panel veri analizi uygulanmıştır. Panel veri analizi sabit ve rastgele etkilerden oluşmaktadır. Teknoloji mülkiyet modelinin sabit etkiler açısından tahmin edilmesine gelince, bu tezde kullanılan metodolojiler farklı sonuçlar vermektedir. Panel fark alma yöntemi ile ilgili tahmin sonuçlarına göre firma büyüklüğü, ihracat payı, yazılım yatırımı, Ar-Ge çalışan başına personel harcamaları, e-bankacılık ve e-eğitim gibi faktörlerin dört teknoloji modeli üzerinde olumlu etkileri bulunmaktadır. Rastgele etki modelinin sonuçları sabit etkiler modelinin sonuçlarına benzerlik göstermektedir. Bununla birlikte alternatif tahmin edicilerin sabit etki tahmin sonuçları, farklı sonuçlar sağlamaktadır. Bu modeller için, sadece firma büyüklüğü ve e-eğitim teknolojisi teknoloji sahipliği üzerinde olumlu etkilere sahiptir.

Değişkenlerin çoğu rastgele etki modelinde önemli iken, sabit etkiler modeli ERP ve CRM teknolojileri kullanımında olumlu sonuçlar vermez. Ihracat payı ise ne sabit etkiler modelinde ne de rastgele etki modelinde önemli sonuç vermez. Ayrı ayrı imalat ve hizmet sektörlerinde teknoloji kullanımına bakıldığında ise, firma büyüklüğü imalat sektöründe ERP kullanımı ile ilgili olumlu ve önemli bir etkiye sahiptir. Hizmet sektöründe ise önemli bir etkisi yoktur. Yabancı payı imalat sektöründe CRM teknolojisi kullanımı üzerinde olumlu ve önemli etkiye sahiptir. Firma büyüklüğü imalat sektörü için CRM teknolojisi kullanımında olumsuz etkiye sahiptir.

Bu tezde, 2003-2007 dönemindeki yazılım yatırımı yoğunluğunun firma performansı üzerindeki etkisi de araştırılmaktadır. İlgili dönemde iki ana gözlem tespit edilmiştir. Bunlardan ilki yazılım yatırımı yapan firma sayısnın azalmasıdır. İkincisi ise, halihazırda yazılım yatırımı yapan firmaların bu dönemde daha fazla yatırım yapmış olduklarıdır. Bu tezde sorulan temel soru ise yazılım yatırımlarında gözlenen bu artışın firma verimliliğine etkisinin olup olmadığıdır. Firma performansı, çıktı değişkeni olan üretim değeri ile ölçülmektedir. Girdi değişkenleri ise sermaye, emek, hammadde, enerji ve yakıttan oluşmaktadır. Teknik verimlilik değişkenleri ise ihracat payı, dış kaynak kullanımı, Ar-Ge personeli harcamaları, yazılım yatırımı ve zaman değişkeni olarak belirlenmiştir. İmalat sektöründe firmaların firma verimliliği üzerinde yazılım yatırımı etkisini ortaya çıkarmak için stokastik sınır yaklaşımı izlenmiştir.

Tahmin sonuçlarına göre yazılım yatırmının teknik etkinlik üzerindeki etkisi olumludur. Bununla birlikte bir diğer maddi olmayan yatırımlardan olan Ar-Ge faaliyetlerinin teknik etkinlik üzerindeki etkileri daha güçlüdür. Bu sonuç, Ar-Ge personelinin varlığı nın yazılım yoğun firmalar için olmazsa olmaz bir faktör olduğunu göstermektedir.

Özetle, bu tezde BİT benimsemesine ilişkin iki temel etki sözkonusudur. Bunlardan ilki kısa vadeli etkilerdir. Kesit analiziyle ölçülen tahmin sonuçlarına göre, firmaya özgü faktörlerin bazıları BİT benimsemesi üzerinde yalnızca kısa vadeli etkilere sahiptir. Bu değişkenler ihracat payı ve ihracat payının karesidir. Bir başka deyişle, ihracat faaliyetleri BİT benimsemesinin iki yıl öncesinde gerçekleştirilirse benimseme davranışı üzerinde olumlu ve önemli bir etkiye sahip olur. Bu etki, gecikme süresi dört yıla uzatıldığında sürekli olmayacaktır.

BİT benimsemesi ve firmaya özgü değişkenlerle ilgili bir diğer bir analiz panel veri analizine dayanmaktadır ve uzun vadeli etkileri içermektedir. Buna göre firmaya özgü kaynakların bir kısmı BİT benimsemesi üzerinde uzun vadeli etkilere sahiptir. Bu değişkenler firma büyüklüğü ve e-eğitim faaliyetleridir. Bu sonuç, büyük firmaların sahip olduğu ölçek avantajlarının uzun vadede de var olacağı anlamına gelmektedir. Buna ek olarak, e-eğitim amacıyla internet kullanımı firmaların BİT benimsemeleri açısından hem kısa vadede ve uzun vadede kolaylaştırıcı etkiye sahiptir.

Tezin ikinci kısmını oluşturan firma verimliliği ve yazılım yatırımları etkisine bakıldığında yazılım yatırımı yoğunluğunda son yıllarda artış gözlemlenmektedir. Diğer yandan, bu artışın teknik etkinlik üzerindeki etkisi araştırma ve geliştirme çalışmaları kadar önemli değildir. Bu sonuç, Ar-Ge personeli varlığının yazılım yatırımından daha önemli olduğunu göstermektedir.

4. Politika Önerileri

Tahmin sonuçlarının ışığında tasarladığımız birtakım politika önerilerine örnek vermek gerekirse bunlardan ilki ölçek etkisi ile ilgilidir. Ölçek etkileri hem kısa vadede hem de uzun vadede teknoloji sahipliği modelindeki tamamlayıcı teknolojilerin benimsenmesini etkilemektedir. Bu tezde teknoloji sahipliği modelindeki firmalar küçük ve orta ölçekli firmalar olduğundan politika önerilerimiz bu firmalara yönelik olacaktır.

Makro düzeyde küçük ve orta ölçekli firmaların emek maliyetlerini azaltmak üzere bir dizi düzenleme yapılabilir. Bu firmalara finansal destek sağlamak bu mekanizmalardan biridir. Orta seviyede bu düzenlemeler birtakım şemsiye organizasyonlar tarafından desteklenebilir. Mikro düzeyde ise firmalar kaynaklarını yeniden tahsis etmeye karar verebilirler.

Pratikte, tek ve iki teknoloji kullanan firmalara yönelik koşullu destek programı geliştirilebilir. Bu politika müdahalesi küçük ve orta ölçekli firmaları içermektedir. Bu müdahale KOSGEB tarafından yürütülecektir. Teknoloji sahipliği modelindeki firmalar Pavitt'in sınıflandırmasında olduğu gibi firma kaynaklarını sağlamada dış desteğe ihityacı olan firmalardan oluşmaktadır. Bu politika ürün ve süreç yeniliği yapan firmaları hedeflemektedir. Kısa vadede KOSGEB tek ve iki teknoloji kullanan firmalara üç ve dört teknoloji kullanmanın avantajları konusunda eğitim verebilir. Bu eğitim neticesinde stratejik planlarını hazırlayabilen firmaların yenilik faaliyetleri sübvanse edilebilir. Sübvansiyon almanın şartı üç ve dört teknoloji kullanmanın avantajlarını ölçebilir hale getirmektir. Sonrasında KOSGEB bu firmaları iki yıllığına izleyebilir. Uzun vadede bu firmaların büyümeleri beklenmektedir.

Politika önerisi gerektiren bir diğer husus firmanın ihracat aktiviteleriyle ilgilidir. Tek ve iki teknoloji üreten firmalar genelde yerli piyasalar için üretim yapmaktadırlar. Bu firmaların ihracat aktivitelerinin düşük olması BİT benimsemelerini de olumsuz yönde etkilemektedir. İhracat aktiviteleriyle ilgili bir dizi avantaj bulunmaktadır. Bunlardan en önemlisi dış bağlantılar yoluyla firmaların birbirlerinden öğrenmeleridir. Örneklemimizde yer alan tek ve iki teknoloji kullanan firmalar sayılan pozitif dışsallıklardan faydalanamamaktadırlar. Ağ dışsallıklarıyla ilgili literatüre bakıldığında bir teknolojiyi benimsemenin faydasının o teknolojiyi benimseyenlerle doğru orantılı olduğu sonucu ortaya çıkmıştır(Katz and Shapiro,1985;1994). Geniş bir ağın parçası olmayı sağlayan ihracat aktiviteleri firmanın iletişim becerilerinin gelişmesi açısından önemli bir rol oynar. En önemlisi, ihracat aktiviteleri yoluyla yeni teknoloji ile ilgili en güncel bilgiye sahip olmaktır.

İhracat aktivitelerinin BİT benimsemesi üzerindeki etkileri konusunda çeşitlilik sözkonusudur. İhracat aktiviteleri benimseme davranışı üzerinde kısa vadeli etkiye sahiptir. Bununla birlikte mobil bağlantı kullanımı üzerinde hem kısa hem de uzun vadeli etkileri sözkonusudur.

Teknoloji sahipliği modelinde en dezavantajlı grup tek ve iki teknolojiye sahip olan firmalardır. Bu firmaların ihracat aktivitelerinin düşük seviyede olması onların teknoloji benimseme davranışlarını da olumsuz etkilemektedir. Bu tezde yer alan firmalar açısından bakıldığında bu firmaların ihracat aktivitelerinin arttırılması için mevcut ihracat faaliyetlerinin içeriği ilgili bakanlıkça araştırılmalıdır. Bu araştırmanın yapılması için Ekonomi Bakanlığı İhracatçı Birlikleri'ni yetkilendirebilir.

Tek ve iki teknoloji kullanan firmaların ihracat aktiviteleri araştırılırken ihracatçı birliktlerine bağlı yetkililer bu firmaları mevcut destek programından haberdar etmek ve onların destek sisteminde yer almama nedenlerini anlamak amacıyla mülakat gerçekleştirebilir. İhracat aktiviteleriyle ilgili bir diğer husus yabancı dildir. Bu firmaların yabancı dili olan nitelikli işgücüne sahip olup olmadıkları mülakatta sorularak nitelikli eleman ihtiyacı olanlara yönelik bir politika müdahalesi geliştirilebilir. Örneğin, üniversite öğrencilerinin staj yoluyla bu firmalarda geçici bir süre istihdam edilmesi hem bu firmalarda beşeri sermayenin gelişmesi hem de üniversite öğrencilerinin deneyim kazanması açısından önemli rol oynayacaktır.

Appendix 14

Curriculum Vitae

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Date of birth:	June 17th,1980
Place of birth:	Mersin, Turkey
Gender:	Female
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MOST RECENT DEGREE

September 2007 – January 2013
Middle East Technical University
PhD in Science and Technology Policy Studies. Thesis: *ICT adoption, Software Investment, and Firm Efficiency in Turkey*

September 2004 – June 2007
Middle East Technical University, Turkey
Master in Science and Technology Policy Studies. Thesis : *Turkish Women's NGOs : A Social Network Analysis.*

September 1998 – June 2002
Istanbul University, Turkey
Bachelor in Public Finance

CURRENT EMPLOYMENT

September 2004 -
Middle East Technical University, Turkey
Research Assistant, Science and Technology Policy Studies Research Center , Middle East Technical University. Main activities coordinated are student counseling and coordination of project activities.

RELEVANT RESEARCH EXPERIENCE
• January 1st, 2006 - June 5th, 2006- Exchange Student in Technology Management Master Program at Eindhoven Technical University, the Netherlands • September 1st, 2008 - August 31st, 2009-Research Fellow at Maastricht Graduate School of Governance, the Netherlands • June 1st - August 1st ,2008- Maastricht Graduate School of Governance Summer School- Economics and Political Sciences Courses • November 21st, 2005 - 25th,2005- Training course on Technology Foresight for Organizers which was organized by UNIDO

LANGUAGE SKILLS			
	Reading	**Speaking**	**Writing**
English	Very Good	Very Good	Very Good

PRIZES/AWARDS	
2007-2008	Year's Thesis Award: Turkish Women's NGOs
2006-2007	Class Performance Award

SELECTED PUBLICATIONS AND PRESENTATIONS OF PAPERS

PAPER PRESENTATIONS

- Akçomak, İ.S., Akdeve, E. and Fındık, D. How do ICT Firms in Turkey Manage Innovation?
  Diversity in Expertise versus Diversity in Markets", Borç Dinamikleri, Finansal İstikrarsızlık ve Büyük Durgunluk, 1-3 Kasım 2012, http://teacongress.org/2012-Kongre-Program-ipages-tr69.cgi

- Fındık,D. (2009). "Norweigan Research Networks", Business Strategies and Technological Innovation s for Sustainable Development: Creating Global Prosperity for Humanity, 11th International Conference Readings Book, Prague/Czech Republic July 7-11,2009, Global Business and Technology Association pp.1285-1290. http://www.gbata.com/docs/2009GBATAReadingsBook.pdf

- Beyhan, B., Dayar,E., Fındık,D. , and Tandoğan, S. (2009), "Comments and Critics on the Discrepancies between the Oslo Manual and the Community Innovation Survey in a Developing Country Context", Presented at " 3rd International Conference on Innovation, Technology and Knowledge Economics" in Middle East Technical University.

- Fındık, D. (2007). "Social Network Analysis of Women NGOs in Turkey". Presented in SUNBELT XXVII. International Network Conference, Corfu, Greece.

  Fındık, D. (2007). "Measurement on Library Websites of Turkish Public Universities". Presented in " Annual Conference on Internet, TOBB University,Turkey, http://inet-tr.org.tr/inetconf11/bildiri/73.pdf

- Erdil, E. Cetin. D. and Findik, D. (2007). `` Effect of Tecnology on Gender Wage Differential: A Panel Analysis'' presented in Annual Conference on Feminist Economics, Sydney, New South Wales.

SELECTED PUBLICATIONS

- Akbulut, Ö.Ö., Mimaroğlu, Ö.H., Fındık, D.,Seymenoğlu, Ö., Almış, O. (2012). Türk Kamu Yönetiminde Teftiş ve İç Denetim, TODAİE, Ankara.

- Erdil, E., Çetin,D. and Fındık, D. (2008). "Effect of Technology on Gender Wage Differential: A Panel Analysis", *Applied Economics Letters*, Vol. 15, Issue 10, pp. 821-825.

- Özman, M. and Fındık, D. "Friends or Foes? A Network Approach to the Relations among Women's Organizations in Turkey, STPS Working Paper Series No:8,www.stps.metu.edu.tr/stpswp/series08/0804.pdf

SELECTED RESEARCH PROJECTS
• 2011- Araştırmacı, Ankara İli Bilgi ve İletişim Teknolojileri Sektör İnovasyon Kapasitesi Stratejik Analizi, Ankara Kalkınma Ajansı Doğrudan Faaliyet Destek Programı, http://ankaraictprojesi.org/images/stories/document /Final_Report.pdf • 2010-Araştırmacı, Bilim ve Teknoloji Çağında Türkiye'de İnovasyon Faaliyetleri, TÜBİTAk, Proje No:107K172, http://www.stps.metu.edu.tr/documents/TUBITAKProjeNo107K172.pdf • 2009-Araştırmacı, Kümeler, Sanayi Ağları ve İnovasyon:Ankara Bölgesi Makine ve Mobilya Sektörleri Örneği, in collaboration with KOSGEB,Metu-Tech, and ASO, http://stps.metu.edu.tr/kusai/KUSAI_SonucRaporu.pdf

Appendix 15

TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü ☐

Sosyal Bilimler Enstitüsü ☐

Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

YAZARIN

Soyadı :Fındık
Adı : Derya
Bölümü Bilim ve Teknoloji Politikası Çalışmaları

TEZİN ADI (İngilizce) : ICT Adoption, Software Investment, and Firm Efficiency in Turkey

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ☐

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
3. Tezimden bir bir (1) yıl süreyle fotokopi alınamaz. ☐

Yazarın imzası: Tarih: