ESSAYS ON THE IMPACT OF KNOWLEDGE ON ECONOMIC GROWTH

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF SOCIAL SCIENCES

OF

MIDDLE EAST TECHNICAL UNIVERSITY

BY

FATMA MUAZZEZ UTKU İSMİHAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE DOCTOR OF PHILOSOPHY
IN
THE DEPARTMENT OF SCIENCE AND TECHNOLOGY POLICY
STUDIES

MARCH 2016

Approval of the Graduate School of Social Sciences

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ABSTRACT

ESSAYS ON THE IMPACT OF KNOWLEDGE ON ECONOMIC GROWTH

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Ph.D., Science and Technology Policy Studies
Supervisor: Prof. Dr. M. Teoman Pamukçu
March 2016, 209 pages

This Ph.D. thesis comprises of three essays on the role of knowledge on economic growth.

The first essay aims to investigate the role of knowledge in the economic growth and catch-up process of the OECD member countries during the 1995-2011 period, by utilizing panel data techniques. The empirical results suggest a positive impact of knowledge indicators on the economic growth performances of OECD countries and that there is convergence to the common long-run equilibrium in OECD.

The second essay analyzes the impact of knowledge on the economic growth performance of Turkey over the 1963-2010 period, by using a production function approach and time series techniques. This essay also introduces a knowledge index to measure various dimensions of knowledge all together. The results indicate that the higher level of knowledge has a positive impact on the growth rate of Turkish economy over the sample period.

The last essay analyzes the impact of knowledge on the productivity of manufacturing firms in Turkey by using firm level panel data from 2003 to 2010 and production function approach. The essay attempts to take earlier studies one step further by utilizing a more comprehensive dataset both in terms of scope and time dimension. The findings indicate that the level of the technological

capability of a firm influences both its ability to utilize R&D and knowledge diffusion, to increase its productivity level.

Keywords: economic growth, catch-up, knowledge, productivity and manufacturing sector.

ÖZ

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Ph.D., Bilim ve Teknoloji Politikası Çalışmaları
Danışman: Prof. Dr. M. Teoman Pamukçu
Mart 2016, 209 sayfa

BİLGİNİN EKONOMİK BÜYÜME ÜZERİNE ETKİSİNE İLİŞKİN MAKALELER

Bu Doktora Tezi bilginin ekonomik büyüme üzerindeki rolünü inceleyen üç makaleden oluşmaktadır.

İlk makale, 1995-2011 döneminde, OECD üyesi ülkelerde bilginin ekonomik büyüme ve yakalama sürecindeki rolünü panel veri analizi kullanarak araştırmaktadır. Ampirik sonuçlar bilgi göstergelerinin OECD ülkelerinin ekonomik büyüme performanslarının üzerinde olumlu etkisinin ve OECD'de ortak bir uzun dönem dengeye doğru yakınsama olduğunu göstermektedir.

İkinci makale, 1963-2010 döneminde, bilginin Türkiye'nin ekonomik büyüme performansına etkisini üretim fonksiyonu yaklaşımı ve zaman serisi teknikleri çerçevesinde analiz etmektedir. Bu makale ayrıca bilginin farklı boyutlarını bir bütün olarak ölçmek için bilgi endeksi sunmaktadır. Sonuçlar bilgi düzeyindeki bir artışın, söz konusu dönemde, Türkiye ekonomisinin büyüme oranı üzerinde pozitif etkisinin olduğunu göstermektedir.

Son makale, Türkiye'de bilginin imalat firmalarının verimliliği üzerindeki etkisini, üretim fonksiyonu yaklaşımı ve firma düzeyinde 2003'den 2010'a kadar panel veri kullanarak analiz etmektedir. Makale, daha önce yapılan çalışmaları hem içerik hem de zaman boyutlarıyla daha kapsamlı bir veri seti kullanarak bir adım ileriye götürmeyi hedeflemektedir. Bulgular, bir firmanın teknik kapasite

düzeyinin bu firmanın hem Ar-Ge hem de bilgi yayılımından faydalanabilme yeteneğini ve dolayısıyla verimlilik düzeyini belirlediğini göstermektedir.

Anahtar kelimeler: ekonomik büyüme, yakınsama, bilgi, verimlilik ve imalat sanayi.

To Nisan and Utku

For always, I will love you both

more than yesterday and less than tomorrow

ACKNOWLEDGEMENTS

First, I would like to thank my supervisor Prof. Dr. M. Teoman Pamukçu for his academic guidance and support throughout the dissertation. His guidance not only improved the quality of my thesis but also increased my technical abilities as a researcher.

I would also like to thank the members of my thesis advising committee Prof. Dr. Fikret Şenses and Prof. Dr. Erkan Erdil who have played great part both in the evolution process of my thesis and in my decision to pursue an academic career. I have been very fortunate enough to be a student of Prof. Dr. Fikret Şenses. The impact of his encouragement and trust in my academic abilities will be a pride that I will cherish throughout my life. I would also like to express my gratitude to Prof. Dr. Erkan Erdil for his guidance and motivation through my Ph.D. journey.

I would like to thank the members of my Ph.D. thesis jury Assoc. Prof. Dr. Ozan Eruygur and Asst. Prof. Dr. Semih Akçomak for their advice that have contributed to the last version of the dissertation. I would also like to thank TurkStat staff particularly, Erdal Yıldırım, Sabit Cengiz Ceylan and Ferhat Irmak for helping me during the period that I have studied in the TurkStat micro data research center.

I would like to thank my dear friend and Ph.D. classmate Asst. Prof. Dr. Elif Kalaycı for her support and motivation that made it much easier to endure the difficulties of working, parenting and pursuing academic studies.

I would also like to thank my parents and sisters for their motivation. Especially Ayşe for her logistic support with the children, that was vital while I was writing my dissertation.

I would like to thank Mustafa İsmihan, my partner for more than two decades, for encouraging me to follow my dreams. Having an economist like him at an arms length was a blessing at times of difficulty.

Last but not least I would like to thank my daughter Nisan and my son Utku for their understanding and mature attitude for the time I had stolen from them while I was writing this dissertation. For always, I will love you both more than yesterday and less than tomorrow and cherish the pride of being your mother.

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LIST OF ABBREVIATIONS

ARDL	Autoregressive Distributed Lag
Ar-Ge	Araştırma ve Geliştirme
GDP	Gross Domestic Product
GMM	Generalized Method of Moment
HAC	Heteroskedasticity and Autocorrelation Robust
ICTs	Information and Communication Technologies
IMF	International Monetary Fund
KI	Knowledge Index
R&D	Research and Development
OECD	Organization for Economic Co-operation and Development
PMG	Pooled Mean Group
PPP	Purchasing Power Parities
PWT	Penn World Table
TFP	Total Factor Productivity
TurkStat	Turkish Statistical Institute
TÜİK	Türkiye İstatistik Kurumu
UNDP	United Nations Development Program
USA	United States of America
WDI	World Development Indicators

CHAPTER 1

INTRODUCTION

Never before in the history of mankind has the world changed as rapidly as it has changed during the last few decades. The global economy is moving towards a "knowledge economy",[1] shaped by various dimensions or pillars of knowledge, such as human capital, research and development, information and communication technologies and international trade. These pillars of knowledge, in turn, have potential to improve the level of productivities as well as accumulation of “inputs”[2] of countries and hence their growth performance. However, the analysis of the impact of knowledge on productivity is not restricted to the overall (macro) economy since the firms are the main (micro) units that engage in research and development activities by employing human capital. Therefore, it is crucially important to analyze the various channels of knowledge on productivity (growth) and catch-up process at various (macro and micro) levels. Consequently, one of the central and intensively researched topics in economics, especially during the last three decades, has been the investigation of the role of various dimensions of knowledge on the economic growth performances and catch-up efforts –generally via productivity and capital accumulation– of countries and firms.

The main aim of this Ph.D. thesis is to investigate the impact of knowledge pillars on economic growth both at macro and micro level, since together they would provide a complementary analysis and hence more insight to the growth dynamics and catch-up process. Accordingly, this thesis comprises of three self

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[1] Drucker (1969) was first to use the term “knowledge economy”.

[2] As will be explained in more detail in Chapter 2, we may consider both human capital and research and development as additional inputs along with the physical capital.

contained essays and each one attempts to contribute new insights to the impact of knowledge on economic growth at macro or micro level.

Chapter 2 introduces the first essay that examines the impact of knowledge on the economic growth performances as well as catch-up efforts of the OECD member countries for the 1995-2011 period. The second essay provided in Chapter 3, examines the impact of knowledge indicators on the economic growth performance of Turkey during the 1960-2010 period. Chapter 4 introduces the last essay which investigates the impact of firms own R&D together with knowledge diffusion variables on the productivity levels of the firms in the Turkish manufacturing sector, during the 2003-2010 period.

The remainder of this chapter provides a review of each essay and the main research questions that have been investigated therein.

1.1. Essay 1: Knowledge, Technological Catch-up and Economic Growth: A Panel Data Analysis for OECD Countries

Some economists, led by Nobel Laureate Robert M. Solow, believed that the technological improvements were freely available to poor countries and that they would eventually converge to income levels of the rich countries. Later, Gerschenkron (1962) and the other "technology-gap" theorists, tried to find out the reasons behind the differences in the income levels across countries and concluded that the *technological differences* were the prime cause of the differences between the income levels of countries and argued that the follower countries[3] were trying to "catch-up" the leading country (in terms of technology) so as to achieve higher growth rates. However, as argued by the technology-gap theorists, by time the follower countries established the necessary infrastructure for the production of the technology, the leading countries with their more advanced research and development (R&D) structures moved forward to new technological frontiers. So, with the

[3] Lagging and following (follower) countries will be used interchangeably throughout the thesis.

exception of a few countries, in general rather than converging, the economic growth gap between the rich and poor countries in the world has increased.

Nelson and Phelps (1966) have formalized Gerschenkrons' (1962) catch up model. They introduced education as the main and the only determinant of the ability to use new technology. Later, Benhabib and Spiegel (1994), in line with the spirit of the new growth theories augmented the Nelson and Phelps' approach by emphasizing the endogenous nature of technological progress. They introduced education as the main and the only determinant of the ability of the follower country to use the technology from the leading country and the rate at which the technological gap between the leader and follower countries would close. That is, human capital has dual role on the technological capabilities of countries. First, it enhances the domestic capability of technological innovation and secondly, it enables the adaptation and implementation of imported technology. Thus, the level of education determines the total productivity of the following countries.

Following the spirit of Gerschenkron (1962) and Benhabib and Spiegel (1994), in this essay our primary concern was to find out whether or not knowledge had impact on the long run growth performance and catch-up efforts of countries, that is, our research question, initially, was: "*What are the roles of knowledge variables in the catch-up efforts of the follower countries in OECD*?"

In the first part of the essay we derive an augmented framework by using Benhabib and Spiegels' (1994) model to study the catch-up process. In this model, our departure from Benhabib and Spiegel's (1994) is that we use R&D, trade and ICT (different channels of knowledge), in addition to human capital, to understand how knowledge contributes to the catch-up efforts of follower countries. Secondly, following Griliches (1980) we also calculated R&D stock based on the perpetual inventory method, rather than using share of R&D expenditure in GDP as a proxy, since the level of knowledge (due to R&D) is a function of past and present levels of R&D spending. Then a multi-country analysis for Organisation for Economic Co-operation and Development

(OECD) countries using panel data from 1995 to 2011 was carried out to examine the diffusion of technology between these countries. More specifically, our research questions are: "*What determines the potential of lagging countries to catch-up the leading countries in OECD?*" and "*How does initial country conditions shape the adaptive and innovative capacity of following countries in OECD?*"

The empirical results were totally disappointing. Majority of the results of our panel data estimation with traditional methods were either theoretically inconsistent or statistically insignificant. Then we tried to understand why we ended up obtaining such controversial results to our a priori theoretical and empirical expectations.

Later, we found that there were serious limitations with the specification used by Benhabib and Spiegel (1994) who were following Nelson and Phelps' specification. Nelson and Phelps emphasize the role of human capital in adaptation/using new technology and hence improving total factor productivity. Thus, human capital enters the model via total factor productivity. Since our model was an augmented version of Benhabib and Spiegel, just like them in our specification we followed Nelson and Phelps and the knowledge indicators (including human capital and R&D stock) entered into the model through total factor productivity.

On the other hand, as introduced by Lucas (1988), when human capital enters the model as an additional input it captures the role of human capital accumulation in the growth process. Thus, in the second part of our essay, following Lucas (1988), we developed a new model where we introduced human capital as an additional input together with capital stock and also included the other critical knowledge variables as a shift factor in the production function (as suggested by Griliches (1979) and Eberhardt et al. (2013)). We named this new production function as *the augmented knowledge production function.*

In this part, rather than using static panel data analysis employed by Benhabib and Spiegel (1994), we utilized dynamic panel data techniques. This new framework provided us the possibility of observing long-run information in the data by focusing on the equilibrium relations. This was not possible with the previous analysis based on Benhabib and Spiegel approach which focused on the differenced form of production function which looses the valuable long run information. Following Peseran et al. (1999) we used pooled mean group (PMG) estimation method where only the long run coefficients are same across countries and the short run coefficients vary.

The results of the PMG estimation of our new production function were both theoretically and statistically significant. That is, our analysis of 34 OECD countries for 1995-2011 period, indicates that knowledge variables as a whole have positive impact on the economic growth performances of OECD countries and the lagging OECD members seem to be converging to the common long-run equilibrium represented by the augmented knowledge production function.

The main finding of this essay was that, as our study evolved, to our surprise we found serious weakness regarding the Benhabib and Spiegel's (1994) model and empirical approach used in this area. As we deepened our investigation we ended up developing a new model and a different empirical approach (PMG). Thus the contribution of this essay is that not only does it provide us with two augmented theoretical models (with two distinct econometric analysis) it also shows us that some of the seminal studies might have serious weaknesses.

1.2. Essay 2: The Role of Knowledge on Economic Growth: The Case of Turkey, 1963-2010

In Essay 2, presented in Chapter 3, the impact of knowledge on the economic growth performance of Turkey over the 1963-2010 period is analyzed by using a production function approach and time series techniques. Basically in this essay we wanted to find out: "*What are the contributions of the knowledge variables on the economic growth performance of Turkey?*"

The contribution of this essay is twofold. First, to our knowledge, earlier studies on the economic growth performance of Turkey, in general, have focused on a single or specific dimension of knowledge, especially on R&D. For example, Kar and Ağır (2004), Özsoy (2009) and Şimşek and Kadılar (2010) have only analyzed different aspects of R&D. Thus, the first contribution of this essay is that it investigates the role of the four dimensions (indicators) of knowledge on economic growth performance of Turkey together for the first time. In doing so, first we attempt to develop an augmented production function model by considering the seminal studies on different strands of endogenous growth models that have focused on various dimensions of knowledge that we are interested in, for example, the human capital[4], R&D[5] and trade[6].

The second contribution of the essay is a knowledge index; constructed to see the impact of various dimensions of knowledge with a single and comprehensive measure of the "level" of knowledge in the economy. The construction of a knowledge index not only provides us with a single and comprehensive measure on the "level" of knowledge in the economy, but it also prevents the potential problem of multicollinearity between the knowledge variables.

The empirical results obtained from the time series analysis indicated that higher level of knowledge had a positive and statistically significant impact on the growth rate of Turkish economy over the sample period. Our results seem to be robust to several sensitivity analysis with respect to the role of knowledge indicators and structural changes.

[4] See for example, Romer (1986) and Lucas (1988).

[5] See for example, Grossman and Helpman (1994), and Aghion and Howitt (1992).

[6] See for example, Grossman and Helpman (1989 and 1991).

1.3. Essay 3: Impact of Knowledge on the Productivity Level of Firms: A Microeconomic Analysis of the Turkish Manufacturing Sector

In Essay 3 (Chapter 4), the impact of knowledge on the productivity of manufacturing firms in Turkey was analyzed by using firm level panel data from 2003 to 2010 and system generalized method of moment (GMM) analysis. The main research question in this essay is: "*What are the impacts of R&D and knowledge spillover variables and knowledge variables on the growth performance of the manufacturing firms in Turkey over the 2003-2010 period*?"

Majority of the firm level studies have focused on factors that contribute to the growth levels of productivity because it simply determines the future existence of firms. The factors that contribute to productivity are either firm specific (size, human capital, R&D investment etc.) or external (industry specific characteristics such as labor mobility and institutional background) or both. For example, Griliches (1992, 1994) points human capital, economies of scale and industry specific factors as the main determinants of firm level productivity.

In terms of catch-up, the arguments are similar to the ones in the first essay. One argument emphasized in the literature is that the diffusion of new knowledge from leading firms to follower firms will eventually result in a convergence of the growth rates of firms.[7] For example, Finlay (1978) in his study has found that the higher the technological distance of follower firms from leader firms the faster the improvement will be in their R&D because there is so much (gap) to catch-up.[8] On the other hand, researchers (such as Cohen and Levinthal (1990)) argue that firms that are more similar to the leader, both in terms of technological knowledge and skills, will engage in similar R&D activities and will reach to the productivity level of the leader much faster than the other (backward) followers. That is, both the degree of

[7] We can consider this argument as the micro level interpretation of the neo-classical model (i.e. Solow (1956)) that we have mentioned in Essay 1.

[8] Findlay (1978) considers the domestic firms as the follower firms and the foreign firms as the leader firms. In our study we will not make such distinction.

heterogeneity and the direction between the leader and the follower determines whether the follower firms will catch-up the leader firm(s).

As in the case of Essay 2, with the exception of few studies, most of the studies on knowledge variables at firm level in Turkey have mainly focused only on different aspects of R&D activities.[9] Without any doubt these studies have provided very useful insights and valuable information in their focused area of investigation.

A very recent and thorough study by Ülkü and Pamukçu (2015) has investigated the impact of R&D and knowledge diffusion channels on the productivity of the manufacturing firms in Turkey during the 2003-2007 period, using the Industry and Service Statistics database of the Turkish Statistical Institute (TurkStat). The results of this study indicate that an increase in R&D intensity leads to increase in the productivity levels of firms that have the threshold level of technological capability. Since this study, to our knowledge, is the most comprehensive study on the role of knowledge variables on the productivity of manufacturing firms in Turkey initially we attempted to elaborate this study with a more enhanced data set in terms of scope and time dimension. More specifically, Ülkü and Pamukçu (2015) have utilized only the Industry and Service Statistics Database in their study especially for the R&D and the foreign trade data, we will take this study further with a unique database that we will establish by combining three different datasets of TurkStat, i.e. the Industry and Service Statistics database, the Foreign Trade database and the R&D database. Apart from being the first data set formed by combining three different datasets another important feature of this data set is that the R&D data is collected according to the Frascati Manual.[10] Due to the availability of longer time period we were also able to

[9] See for example Lenger and Taymaz (2005), Özçelik and Taymaz (2008), Taymaz and Üçdoğruk (2009) and Pamukçu and Erdil (2011).

[10] The Frascati Manual defines R&D as “creative work undertaken on a systematic basis in order to increase the stock of knowledge of man and society, and the use of this stock in order to devise new applications” (OECD, 1993:29).

extend the time period to 2010; thus, another contribution of our dataset is that it contains data for a longer period of time, i.e. 2003-2010.

Therefore, in the last essay we will investigate "*the role of R&D and knowledge diffusion channels on the productivity of the manufacturing firms and impact of absorptive capacity of productivity by using extended dataset from 2003 to 2010*".

The empirical results of the essay supports the findings of Ülkü and Pamukçu (2015) with regards the importance of physical capital stock, in-house R&D stock, the level of market concentration, trade, technological capability and foreign ownership as the determinants of R&D activities of the manufacturing firms in Turkey. Our results also point technological capability as an important determinant of the firm's ability to use the available R&D in the industry. The most important divergence between our estimation results and Ülkü and Pamukçu's (2015) estimation result is that in our results R&D spillovers and R&D spillovers from foreign firms have no significant impact on productivity at all three (minimum, mean and maximum) levels of technological capability in both full and domestic samples. This result reflects that there is serious problem with regards R&D investment in the Turkish manufacturing sector. As mentioned previously the time dimension of our dataset is extended to 2010. Our results may be interpreted as the adverse effects of global financial crisis and increasing international competition on the R&D investment efforts of firms in the Turkish manufacturing sector. That is, due to the crisis the role of these factors have decreased in the Turkish manufacturing sector over the extended period (2008-2010).

In sum, despite addressing three distinct topics each of the three essays aim to shed new light on the impact of knowledge on growth –via productivity and/or capital accumulation- at macro and micro level. In particular, they examine the role of key knowledge pillars (human capital, R&D, international trade and ICTs) on the catch-up efforts of lagging OECD countries (Essay 1); on the overall economic growth performance of Turkey (Essay 2); and on the productivity of firms in the manufacturing sector in Turkey (Essay 3).

CHAPTER 2

KNOWLEDGE, TECHNOLOGICAL CATCH-UP AND ECONOMIC GROWTH: A PANEL DATA ANALYSIS

The neoclassical economists led by Robert Solow believed that the technological improvements were freely available to poor countries and their economies would eventually converge to the income levels of the rich countries (Solow, 1956). However rather than converging the gap between the rich and poor countries persistently increased. Gerschenkron (1962) indicated that the *technological differences* were the prime cause of the persistent differences between the per capita income levels of countries.

Later, studies based on endogenous (new) growth models, emphasized the importance of knowledge diffusion channels, such as R&D, human capital and ICTs, in improving the technological capabilities of countries. It is pointed out that among these knowledge diffusion channels, especially, human capital and R&D play a critical role in enhancing technological capabilities.[11]

In their study Nelson and Phelps (1966) have formalized Gerschenkrons' (1962) catch up model and introduced education (human capital) as the main and the only determinant of the ability of the follower country to use the technology produced by the leading country and the rate at which the technological gap between the leader and follower country would close. Benhabib and Spiegel (1994), in line with the spirit of the new growth theories, augmented the Nelson and Phelps' approach by emphasizing the endogenous nature of technological progress. That is, they assumed that an increase in human capital directly increases the level of growth in total factor productivity.

[11] See seminal studies by Lucas (1988), Romer (1986), Romer (1990), Grossman and Helpman (1994) and Aghion and Howitt (1992) for more detail.

While Benhabib and Spiegel (1994) and Nelson and Phelps (1966) modeled the role of human capital in economic growth through total factor productivity (Nelson and Phelps Approach), seminal empirical studies such as Bosworth and Collins (2003), Inklaar and Timmer (2013) and Senhadji (2000) emphasized that it is important to consider human capital as an additional input along with capital in the production function (Lucas Approach).

Therefore, in this chapter, firstly we develop an augmented framework by using Benhabib and Spiegel's (1994) model to study the catch-up process. Our point of departure from Benhabib and Spiegel's (1994) is that we use other channels of knowledge (R&D, trade and ICT), in addition to human capital, to understand the catch-up efforts of countries. Moreover, following Griliches (1980) we also calculated R&D stock based on the perpetual inventory method since the level of knowledge (due to R&D) is a function of past and present levels of R&D spending. Then a multi-country analysis for Organisation for Economic Co-operation and Development (OECD) countries using panel data from 1995 to 2011 is carried out to see the diffusion of technology between these countries.[12] That is, we will investigate the potential of lagging countries to catch-up the leading country and to see how initial country conditions shaped the adaptive and innovative capacity of following countries.

Secondly, since our main concern is to see the impact of knowledge on the long run growth performance of OECD countries, we also perform a dynamic panel data analysis by using ARDL approach of Peseran et al. (1999). Following Bosworth and Collins (2003) among others we utilize a production function with a skill adjusted labor input [human capital]. Additionally, in line with Griliches (1979) and Eberhardt et al. (2013), we include the other critical knowledge variables as a shift factor in the production function without affecting the returns to inputs. Once again we conduct a multi-country analysis

[12] Initially, we attempted to include all countries in our sample. However, we faced serious data problems, especially for developing and less developed countries. Thus, the main reason for selecting OECD member countries is mainly related to the availability of relatively more dependable, concise and comparable data for knowledge indicators.

on OECD countries, using pooled mean group (PMG) estimation method of Peseran et al. (1999), from 1995 to 2011.

The following section presents a brief overview of the economic developments of the OECD countries during the 1995-2011 period, the next section reviews the theoretical and empirical studies and is followed by Section 2.3 which introduces our technological catch-up model. Section 2.4 presents information regarding the data and the empirical results. Section 2.5 provides an augmented knowledge production function and the results of our dynamic data analysis. Finally, the concluding remarks are provided in Section 2.6.

2.1. An Overview of the OECD Economy during the 1995-2011 Period

OECD was established on 14 December 1960 by 20 countries which signed the convention on the Organisation for Economic Co-operation and Development. The aim of OECD is to promote policies aiming economic and social well being in the world. Since its establishment 14 countries have joined the OECD.[13]

Majority of the OECD members are high income countries that are the leading actors in the global economy. This can be also observed from Figure 2.1 which presents the time plot of the growth rate of OECD countries for 1995-2011 period.

During the early years of the new millennium there has been serious decline in the economic activity of the high income countries (mainly due to 9/11), especially the European Union members and the USA. However, as can be seen from Figure 2.1 the major crisis during the 1995-2011 period occurred in 2008-2009. The global financial crisis of 2008-2009 was triggered by the mortgage crisis in the USA. The annual GDP growth rate in OECD dropped severely from an average of around 3% during 1995-2007 period to -4%

[13] Appendix 2.A provides the list of OECD member countries.

(2009). However a year later from the crisis (2010) the annual GDP growth rate once again reached to 2%.

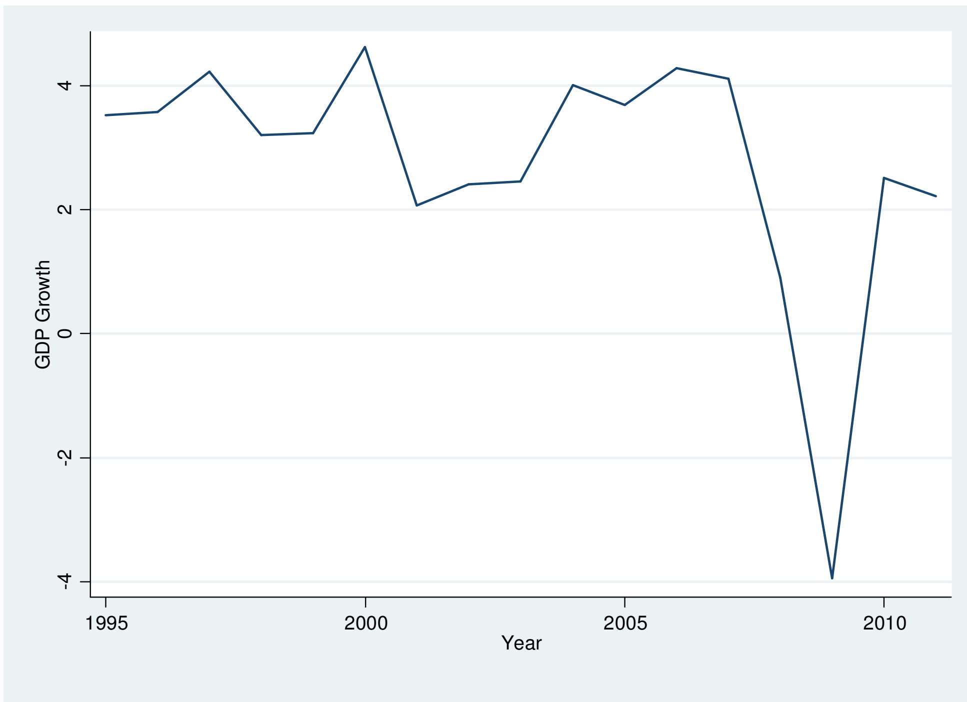

Figure 2.1. Growth Rate in OECD (% Change in Real GDP)[14]

The improvements in transportation and communication technologies (as well as decrease in their costs) along with special agreements among some countries (such as increasing regional economic integrations, free trade agreements and so on) that shaped the current global structure have all contributed to the increase in the volume of trade in the world and even more so for OECD countries. As can be seen from Figure 2.2 the share of trade (export plus import) in GDP has increased from 73% (1995) to approximately 100% (2011) during the 1995-2011 period albeit temporary falls during the turbulent times.

[14] Source: Computed by using WDI data.

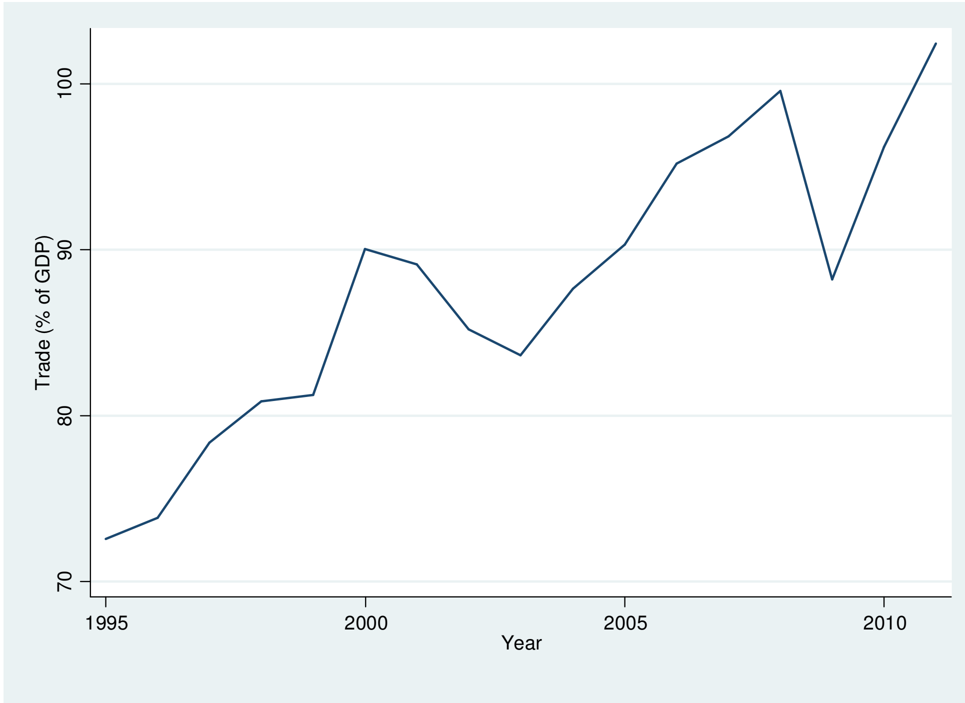

Figure 2.2. OECD Trade (% of GDP)[15]

Research and development (R&D) is considered to be one of the key determinants of economic growth. In order to increase their competitiveness, all countries including the high income and middle high income countries are increasing their expenditures on R&D. Figure 2.3 provides the share of R&D expenditure in GDP for OECD. The R&D expenditure to GDP ratio in OECD has increased from 1.5% (1995) to 2.06% (2011) (see Figure 2.3). However, the R&D expenditure to GDP ratio in OECD countries is between 1% and 4%. For instance, Israel with average R&D to GDP ratio of approximately 4% during the 1996-2011 period is the leading country followed by Sweden, Finland and South Korea with a R&D to GDP ratio above 3.5%.

[15] Source: Computed by using WDI data.

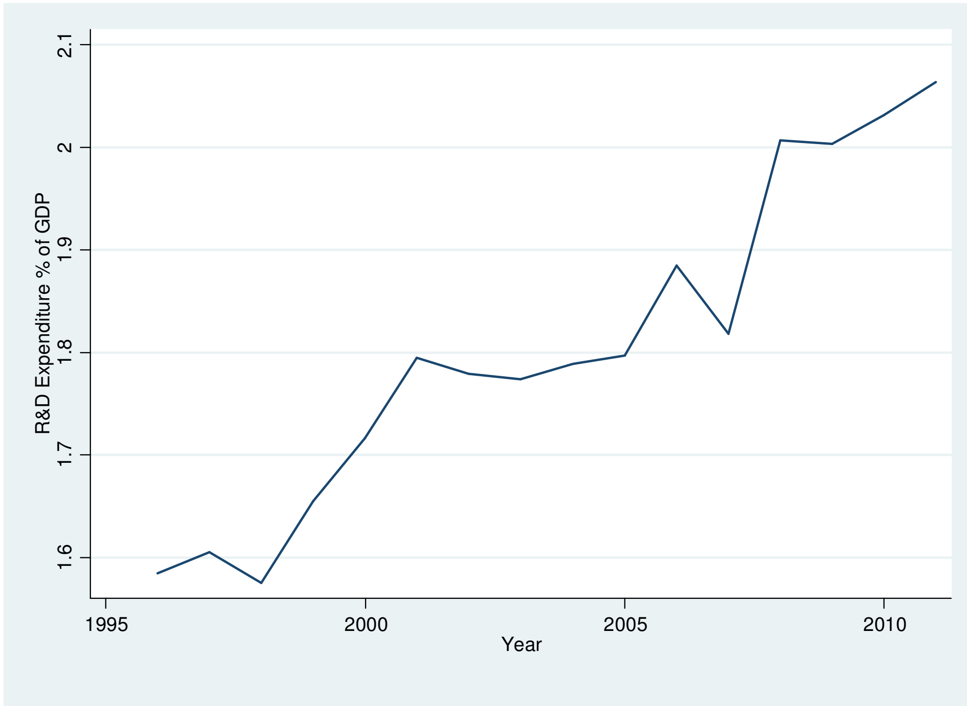

Figure 2.3. R&D Expenditure (% of GDP) in OECD[16]

When we analyze the human capital we see that the index of human capital per person[17] has been steadily increasing in OECD (see Figure 2.4).

The improvements in the information and communication technologies (ICTs) during the late 20th and 21st century have changed and shaped the current world structure. Communication and information are the essentials of daily life in the current century. Never in the history of mankind has there been so much information available to everyone in the world, at virtually zero cost, once the necessary infrastructure to use ICTs has been built.

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[16] Source: Computed by using WDI data.

[17] The index of human capital per person is usually measured by using the Mincerian approach; in which human capital is calculated as a function of average years of schooling and returns to education. Following the literature in PWT 8, data on average years of schooling (Barro and Lee, 2012) and returns to education (Psacharopoulos, 1994) has been combined within a Mincerian approach to calculate the index of human capital per person (Inklair and Timmer, 2013:37).

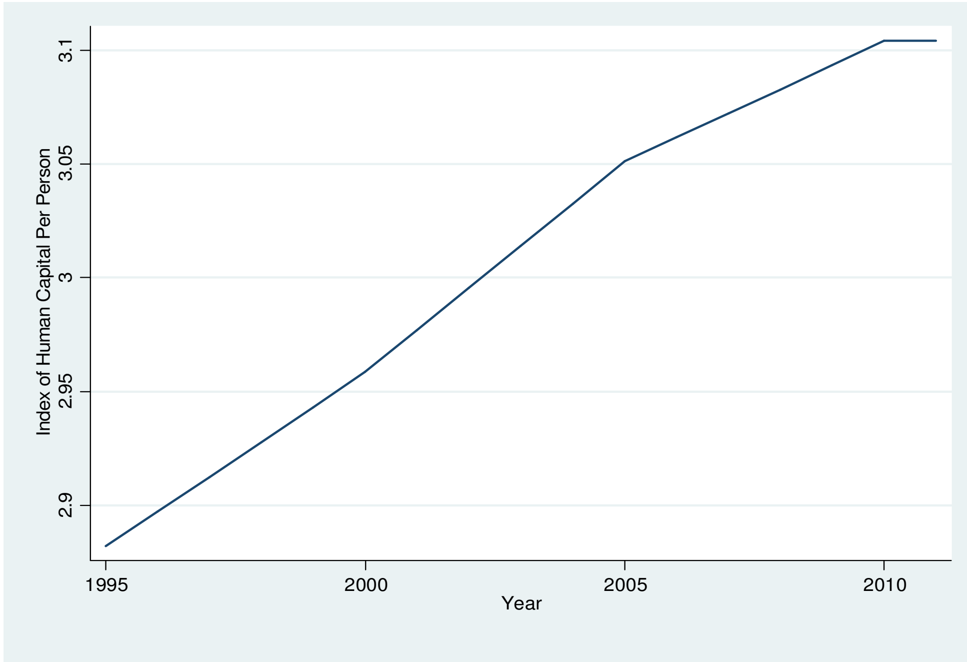

Figure 2.4. Human Capital in OECD[18]

The internet technology, initially developed for military communication, started to be used widely during the late 1990s. The speed of increase in the internet users has been quite significant during the last 15 years. As can be seen from Figure 2.5 the internet users in OECD have increased from 2.9 per 100 persons (1995) to 75.5 per 100 persons (2011). Usage of internet is fundamentally high in OECD countries compared to the rest of the world.[19]

In the following section we provide an overview of the theoretical and empirical literature.

[18] Source: Computed by using PWT data [see Section 2.4.2].

[19] For example, the internet users in the world have increased from 0.04 per 100 persons (1995) to 32 per 100 persons (2011).

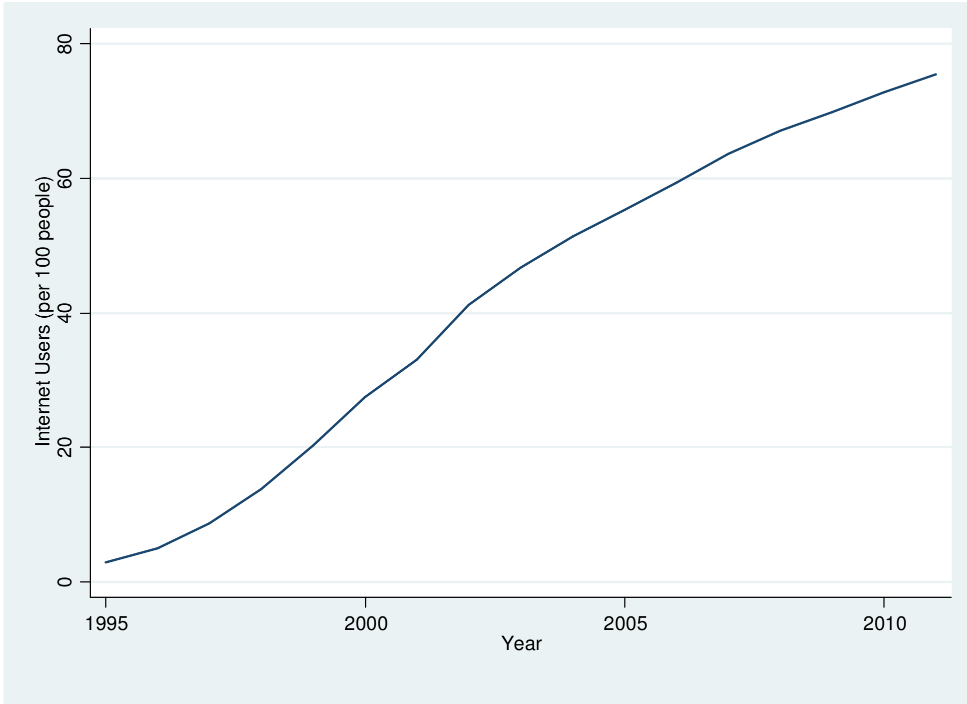

Figure 2.5. Internet Users (Per 100 People) in OECD[20]

2.2. An Overview of Literature

The most important prediction of the neoclassical (Solow) growth model is the convergence hypothesis. According to this hypothesis, in the long run, due to their higher growth rate (as expected from the diminishing returns assumption) poor countries would eventually converge to the per capita income levels of the rich countries. However, in reality with the exception of few countries, especially the East Asian countries, the opposite happened and the income gap between the poor and rich widened. Gerschenkron (1962) was one of the first economists who drew attention to the difficulty for follower countries to catch up with the leading countries. He underlined the institutional resistance to change and the high cost of factors of production, especially human capital which he refers to as the creation of industrial labor force which is "… a most

[20] Source: Computed by using WDI data.

difficult and protracted process…" (Gerschenkron, 1962:9). Thus in reality, by the time the follower countries transfer and use the existing technology, the leader country moves forward to a new technological frontiers (Forbes and Wield, 2000). Thus, the "technology-gap" theorists, led by Gerschenkron (1962), saw "technological differences as the prime cause for differences in GDP per capita across countries" (Fagerberg, 1994:1155). Additionally they pointed out that technology is not freely available to everyone and this is the major obstacle in the catch-up performances of countries.

Nelson and Phelps (1966) in their study emphasized that education (i.e. human capital) determines the ability of the follower country to adapt technology received from the leading country. Thus human capital determines the rate at which the technological gap between the leader and follower country would close.

The basic idea behind the Nelson and Phelps (1966) catch-up model is that the tacit (disembodied) knowledge flow from the leader to the follower and the followers' ability (i.e. education level) to acquire this knowledge determines the speed of the catch-up. That is, human capital accumulation (or education) enhances both the ability of a country to adapt frontier technologies.[21]

$$\frac{\dot{A}_t}{A_t} = c(h) \left[\frac{T_t - A_t}{A_t}\right] \tag{2.1}$$

where A is the total factor productivity, $\dot{A}/A$ denotes the growth rate of A, h is the human capital and T_t is the theoretical level of technology.[22]

[21]That is, human capital as a factor of production (Lucas Approach) is not sufficient enough for catch-up (see Lucas (1988)); it is the ability of the human capital to develop and to implement the transferred knowledge that determines the speed of catch-up (Nelson and Phelps Approach). See Section 2.4.3 for more discussion.

[22] Nelson and Phelps (1966) define theoretical level of technology as "the best practice level of technology that would prevail if technological diffusion … [is realized and] … is a measure of the stock of knowledge or body of techniques available to innovators" (Nelson and Phelps, 1966:71).

Equation (2.1) indicates that the speed of convergence (i.e. the rate of closing the technological gap) depends on the level of human capital. That is, in the short run, the level of human capital determines the rate that theoretical knowledge will accumulate to catch-up with the edge technology, i.e. $\partial c/\partial h>0$. Thus the main contribution of Nelson and Phelps (1966) is that education is not inserted directly into the production function since it "may constitute a gross misspecification of the relation between education and the dynamics of production" (Nelson and Phelps, 1966:75). However, in line with Solow's model, theoretical knowledge is assumed to grow at a constant (exogenous) rate. This means that the growth rate of Solow's residual ($\dot{A}/A$) reaches to that of the theoretical knowledge level in the long-run.

Later, in line with the spirit of the endogenous growth theories, Benhabib and Spiegel (1994) augmented the Nelson and Phelps' approach by emphasizing the endogenous nature of technological progress. They endogenize the productivity by introducing "law of motion for productivity" where the change in productivity is a function of human capital and the technology gap.[23] Benhabib and Spiegel (1994) also introduce a catch-up term which is created by interacting human capital with the technology gap. In line with Nelson and Phelps Model, in this set up there is a leading country and the followers are trying to catch-up its level of technology. The followers' growth rate of total factor productivity (Solow residual) is as follows;[24]

$$\frac{\dot{A}_{it}}{A_{it}} = g(h_i) + c(h_i)\left[\frac{\max_j A_{jt} - A_{it}}{A_{it}}\right] \tag{2.2}$$

[23] Technology gap is the country's distance to the technological frontier.

[24] They utilize the following production function $Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta}$.

where A_{it} is the total factor productivity of the follower at time t, A_{jt} is the total factor productivity of the leader at time t, $g(_{hi})$ is the "endogenous" growth rate and h_i is the followers level of human capital.

In Equation (2.2) the change in productivity depends on the stock of human capital. In this specification the level of education has two roles on the technological capabilities of a country. First it enhances the domestic capability of technological innovation and secondly it enables the adaptation and implementation of imported technology. Thus, the level of education determines the total productivity of the following countries.

The last term gives us the technology gap, country i's (follower country) technology gap is the difference between the country j's (leader country) productivity and the productivity of country i, divided by the follower's productivity.

Initially, the leading country is the one that has the highest TFP. However, if there is another country with a higher level of education, lets' say Country B, then eventually Country B will become the leader, until it has lost its educational advantage to another country.

It is also assumed that in the long-run all countries grow at the same rate as they try to catch-up with the leading country that has the highest level of human capital. In general the countries with lower level of Solow residual have growth rates that are higher than the leader due to the catch-up effect. However, the ones which are close to the leader, in terms of both technology and educational level, have lower growth rates and hence the catch-up effect might become insignificant.

Benhabib and Spiegel (1994) used cross-country estimates of physical and human capital stocks of 60 countries between 1965 to 1985 period. First they found that human capital entered insignificantly in explaining per capita growth rates. Then they have specified an alternative model where the growth rate of total factor productivity is dependent on a nation's human capital stock level and found a positive result. As mentioned above by adapting the Nelson and Phelps (1966) framework they also analyzed the diffusion of technology between countries. They have found that countries with higher education level catch the leading country much faster than the ones that had relatively lower educational attainment.

In a more recent paper Benhabib and Spiegel (2000) specified a panel data version of the model set out in Equation (2.2). They consider Cobb-Douglas form

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} \nu_{it} \tag{2.3}$$

and specified the following structural (catch-up) equation for the TFP.

$$\Delta a_{it} = c + g h_{it} + m \left[\frac{h_{it}(y_{\max t} - y_{it})}{y_{it}} \right] + \varphi . t + \theta . i \tag{2.4}$$

where a_{it} is the total factor productivity of the follower ($a_{it}=\ln(A_{it})$, Δ is the difference operator, $\Delta a_{it}= a_{it} - a_{it-1}$, y_{maxt} is the total factor productivity of the leader (proxied by per capita income), $g(h_i)$ is the "endogenous" growth rate, t and i are the time and country specific fixed effects.

As can be seen the catch-up term is the interaction of human capital with the technology gap defined as the real per capita GDP of the follower country relative to the leader. In this specification when the per capita GDP of a follower country equals the per capita GDP of the leader, the gap is zero. That is, the leading country -via the catch-up effect- drags the other countries along and in general the countries that are closer to the leader have lower growth rates compared to the countries that lag behind due to the catch-up effect.[25]

[25] See, for example, Benhabib and Spiegel (2000) and Engelbrecht (2001) for further details.

Finally, it should be noted that the full model of growth is obtained by combining the log difference of Cobb-Douglas function with Equation 2.4.

The following section introduces our augmented model of technological catch-up.

2.3. The Augmented Models of Technological Catch-up

2.3.1. The Missing Channels in the Literature

According to Nelson and Phelps' approach (including Benhabib and Spiegel's contribution) the level of education alone –more broadly, human capital– determines the gap between the leader and the follower countries, and hence the speed of technological catch-up. Even though the potential of the catch-up growth rates of the followers that are way behind the technological frontier are higher than the ones that are straight behind the leader, some of them may not fulfill this potential due to the absence of other channels of knowledge that facilitate the diffusion of technology. There are number of well known channels (or pillars) of knowledge that helps countries to speed up their technological catch-up and hence economic growth. For example, the economic structure (e.g. openness to foreign trade) of the economy (O), education (h), country's level of R&D stock (R) and country's information and communication infrastructure (I).[26]

Thus, in addition to (as well as interacting with) human capital, the diffusion of technology is affected by trade, ICTs and domestic R&D efforts. Now, we will provide a brief review of the related literature on these channels starting with the human capital.

Human capital channel. Based on our theoretical intuition and the empirical results in the literature we expect human capital to have positive impact on the

[26] See Chen and Dahlman (2004) for more detail.

growth rate of the country.[27] For example, Cohen and Soto (2001) on their analysis 95 countries for 1960-2000 period found that education had a positive effect on economic growth. However, as noted by Kruger and Lindahl (2001), model specification and the measurement of human capital are highly important for assessing the role of human capital on economic growth with macro data.

R&D channel. R&D is both an important determinant of innovation and promoter of technology transfer by raising the absorptive capacity.[28] There seems to be ambiguity with regards the impact of R&D on TFP. While some economists have found that R&D had significant positive impact on TFP and thus on growth performances of the economies (see for example, Coe and Helpman (1995)) some economists have found significant negative impact on TFP due to the uncertainty and ambiguity that R&D entails due to its nature (see for example, Cozzi and Giordani (2011)).[29]

Trade channel (Openness to Foreign Trade). Trade increases the innovation capability of a country through the transfer of embodied technology with the imported capital goods and ideas (patents and licenses) or feedbacks from exported goods.[30] Moreover, by importing technologically intensive products the follower countries can increase quality of their products and their production efficiency. Thus, as argued by Coe et al. (1997) if trade involves positive externalities such as embodied knowledge then it would have positive impact. However, the impact of openness on economic growth depends significantly on the absorptive capacity of the country. For example, Fagerberg

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[27] For example, Benhabib and Spiegel (1994, 2000 and 2004), Cohen and Soto (2001), Collins et al. (1996) and so on find that education has positive effect on economic growth.

[28] See, for example, Griliches and Lichtenberg (1984), Griliches (1992) and Aghion and Howitt (1992) on R&D as the determinant of innovation and Geroski (2000) and Griffith et al. (2000) for R&D and absorptive capacity.

[29]See Welch (1975), Bartel and Lichtenberg (1987), Coe and Helpman (1995), Caselli and Coleman (2001), Caselli and Wilson (2004), Xu (2000) and Benhabib and Spiegel (2005) for more detail.

[30] Coe and Helpman (1995) have found that this had a positive impact on domestic productivity.

and Srholec (2008) in their analysis for 115 countries during 1992 -2004 period found that the trade (or "openness") is influenced by the absorptive capacity of the country. That is, the absorptive capacity of the country determines the impact of trade on economic growth.[31] So, interactive effect of trade via catch-up efforts of the country on growth is an important issue.[32]

ICT channel. ICTs on the other hand provide a channel for fast and effective flow of technological knowledge which also has a positive impact on the domestic productivity.[33] The impact of ICTs on productivity has been through various channels. For example, the continuously decreasing computer and software prices has led to the incentive of replacing other capital goods with them and this in turn contributed to higher total factor productivity growth. The computerization along with the developments in other ICTs, such as internet, made it much easier to acquire information from suppliers and/or customers to develop new products or processes. Some country specific studies have found that ICT usage had an important impact on TFP (see for example Jorgenson and Stiroh (2000)). Moreover, OECD (2012) in a recent report considers ICT to be a general purpose technology that changed the world drastically. This can be attributed to ICTs both direct and indirect affect on growth and productivity.

Based on theory it is expected that all ICTs would boosts knowledge creation and have positive impact on TFP and thus economic growth of countries.[34] However, there seems to be ambiguity in terms of empirical studies. For

[31] Fagerberg and Srholec (2008) use trade and foreign direct investments to proxy for openness of an economy and find that "…openness to imports and foreign direct investment seems to matter more for the richer economies … poor countries due to lack of absorptive capacity are much less likely than other countries to benefit from foreign direct investments ... [a]lthough a positive correlation between openness and growth is reported … [it is] sensitive to changes in the composition of the sample…it is among the richer economies that openness to trade and foreign direct investment seems to matter most for growth (Fagerberg and Srholec, 2008: 1422-1427)".

[32] See section 2.3.3 for detail.

[33] For example, the ICTs provide the opportunity of an efficient, continuous and permanent connection to the global markets, which increases the flow of information into the economy. This newly acquired information, in turn, contributes to productivity increase.

[34] See, for example Aghion and Howitt (1998) and Barro and Sala-i-Martin (2003).

example, OECD (2012) in a study on the impact of internet in OECD countries has found that the impact of internet on the per capita income growth across the countries varied among countries, while there was positive impact in US, this did not hold for all the other OECD members (even in some of the European countries). In terms of the less developed countries since there is limited access for the capital required to build the internet infrastructure and impact of ICT does not seem to be significant.[35] On the other hand, Choi and Yi (2009) in their study for 162 countries during 1991-2000 period found that the internet to have a positive and significant role in economic growth. Thus, taking into consideration the evidence provided by the empirical research just like in the case of openness we do not have a priori expectations with regards ICT.

Comin and Hobijn (2004) investigated the evolution of 25 technologies in 23 countries during a span of 200 years. They found that most new technologies originated in rich countries and the following countries were slow to adopt these new technologies. Comin and Hobijn (2004) found that the speed of adoption is positively related to per capita GDP, human capital, and openness to trade, and is also related to the type of government.

In the light of these arguments, the Nelson and Phelps' framework and Benhabib and Spiegel (2000) framework needs to be augmented by incorporating these additional channels that can help technological diffusion and catch-up. We will attempt to do this in the following sub-section.

2.3.2. Knowledge and Technological Catch-up: The Augmented Approach

In the Benhabib and Spiegel (1994) framework (Equation 2.2) the technology gap is a function of human capital (h_i). They emphasize the role of human capital for the growth process of countries through its impact on productivity growth. That is, the potential for catching up of countries, with a technology

[35] See, Kenny (2003) for more detail. Also several other studies have negative impact of ICT on economic growth especially for the developing countries (Dewan and Kraemer (2001) and Satti and Nour (2003)).

gap, depends on the country's absorptive capacity which is proxied by human capital.

In our model, starting with a production function as in Benhabib and Spiegel (1994) framework, different channels of knowledge are used to determine the speed to catch-up the leading country. That is for (follower) country i the growth rate of total factor productivity will be as follows:

$$\frac{\dot{A}_i(t)}{A_i(t)} = \mathrm{f}\,(\mathrm{h, R, O, I}) + \mathrm{h}\left[f(.)(\max A_j(t) - A_i(t)) / A_i(t) \right] \qquad (2.5)$$

where h is the human capital, R is research and development, O is trade, I is information and communication technologies and other variables are as defined earlier.

There are several important points regarding this set-up. First, the level of knowledge represents the overall ability of a country to use and imitate available technologies and, more importantly, the ability to innovate new technologies. In other words, knowledge has two effects on total factor productivity. It helps both to use and improve imported technologies $\left[\mathrm{f}\,(\mathrm{h, R, O, I})\ (\max A_j(t) - A_i(t)) / A_i(t))\right]$ and it is the basis for the ability to innovate new technology.

Secondly, in this framework "broad level" of knowledge –via *four* different channels– rather than human capital alone (as in Benhabib and Spiegel's framework) determines the speed of catch-up and the diffusion of technology.

2.3.3. Structural Specification

This section provides structural specification for Equation (2.5).

In line with Benhabib and Spiegel (2000) first we consider the following Cobb-Douglas production function,

$$Y_{it} = A_{it} K_{it}^{\theta_1} L_{it}^{\theta_2} \tag{2.6}$$

where A is TFP,Y is output, K is capital and L is labor of country i at time t.

Following Benhabib and Spiegel (2000) we imposed constant returns to scale $(\theta_1 + \theta_2 = 1)$ equation (2.6) can be rewritten in per capita log linear form as follows,

$$y_{it} = a_{it} + \theta_1 k_{it} \tag{2.7}$$

where y=ln(Y/L), a=lnA and k=ln(K/L).[36]

After taking the first difference it can be rewritten as follows in per worker growth form,

$$\Delta y_{it} = \Delta a_{it} + \theta_1 \Delta k_{it} \tag{2.8}$$

[36] For the sake of simplicity we use the terms “per worker” and “per capita” interchangeably throughout this thesis.

where Δx is the growth rate of X (i.e. log difference of X) and all other variables are as defined earlier.

As is clear from Equation (2.8) the growth rate of output is related to the growth rates of total factor productivity (A) and physical capital (K). Total factor productivity is, in turn, dependent on the level of knowledge.

As mentioned previously, one of the objectives of this chapter is to investigate the role of knowledge in the catch-up process–via total factor productivity. In doing so, by augmenting the Benhabib and Spiegel's (2000) framework the speed of catch-up and diffusion of technology for follower countries is modeled as follows:

$$\Delta a_{it} = \alpha_0 + \alpha_1 h_{it} + \alpha_2 R_{it} + \alpha_3 O_{it} + \alpha_4 I_{it} + \beta_1 h_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right]$$
$$+ \beta_2 R_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right] + \beta_3 O_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right] + \beta_4 I_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right] \qquad (2.9)$$

where Yp_{it} is the per capita output of country i at time t, Yp_{maxt} is the per capita output of the leading country at time t, $[(Yp_{maxt}/ Yp_{it})/ Yp_{it}]$ represents the economic backwardness (*technological gap*) of country i and all the variables are as defined before.

In Equation (2.9) the first four terms represent the endogenous technical progress (ability) of country i at time t to innovate and the second four terms show the catch-up effects. That is, in this set-up there is a leading country and the speed at which the other countries catch the leader is a function of the factors of knowledge, which, in turn, depends on the various channels (pillars) of knowledge as explained before. Following Benhabib and Spiegel (2000) and others in this model the leader country is assumed to be USA.

By combining Equation (2.8), Equation (2.9) and introducing panel fixed effects (by following Benhabib and Spiegel, 2000), we obtain the following (fully specified) model:

$$\Delta y_{it} = \alpha_0 + \alpha_1 h_{it} + \alpha_2 R_{it} + \alpha_3 O_{it} + \alpha_4 I_{it} + \beta_1 h_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right]$$

$$+\beta_2 R_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right] + \beta_3 O_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right] + \beta_4 I_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right]$$

$$+\theta_1 \Delta k_{it} + \gamma t + \phi i \qquad (2.10)$$

where all the variables are as defined earlier and t and i are the time and country specific fixed effects.[37]

In the above complete specification (fully specified model) we introduce all four knowledge indicators directly into the model (Equation 2.10); however, it should be noted here that Benhabib and Spiegel's (2000) model can be considered as a special case of the above model ($\alpha_2 = \alpha_3 = \alpha_4 = 0$ and $\beta_2 = \beta_3 = \beta_4 = 0$). That is,

$$\Delta y_{it} = \alpha_0 + \alpha_1 h_{it} + \beta_1 h_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right] + \gamma t + \phi i + \theta_1 \Delta k_{it} \qquad (2.11)$$

where all the variables are as defined earlier.

[37] Introduction of country-specific variable (i) is aimed to capture heterogeneity due to country specific factors (e.g. institutional environment). Similarly, time variable (t) is aimed to capture the overall changes in growth across time such as time-specific effects of global economic crisis.

Along with the Benhabib and Spiegel (2000) model (Equation 2.11) we also consider other special cases to check whether our results would change empirically, if we introduced the four dimensions (indicators) of knowledge on growth separately. As we shall explain later, this is particularly important when we consider the potential detrimental effects of possible multicollinearity between knowledge indicators.[38] Hence, we also consider the following special cases,

$$\Delta y_{it} = \alpha_0 + \alpha_2 R_{it} + \beta_2 R_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right] + \gamma t + \phi i + \theta_1 \Delta k_{it} \tag{2.12}$$

$$\Delta y_{it} = \alpha_0 + \alpha_3 O_{it} + \beta_3 O_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right] + \gamma t + \phi i + \theta_1 \Delta k_{it} \tag{2.13}$$

$$\Delta y_{it} = \alpha_0 + \alpha_4 I_{it} + \beta_4 I_{it} \left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}} \right] + \gamma t + \phi i + \theta_1 \Delta k_{it} \tag{2.14}$$

2.4. The Empirical Models, Data and Results: The Augmented Technological Catch-up

2.4.1. Empirical Strategy and the Models

Equation (2.10) is re-stated for empirical purpose in stochastic form as follows[39]

[38] The result of this analysis is provided in Section 2.4.3.

[39] Following Benhabib and Spiegel (1994, 2000) and Inklaar and Timmer (2013) among many others, USA is selected as the leader country.

$$\Delta y_{it} = \alpha_0 + \alpha_1 h_{it} + \alpha_2 R_{it} + \alpha_3 O_{it} + \alpha_4 I_{it} + \beta_1 h_{it}\left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}}\right]$$

$$+\beta_2 R_{it}\left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}}\right] + \beta_3 O_{it}\left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}}\right] + \beta_4 I_{it}\left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}}\right]$$

$$+\gamma t + \phi i + \theta_1 \Delta k_{it} + \varepsilon_{it} \tag{2.15}$$

where all the variables are as defined before and ε_{it} is the error term.

Based on the related theoretical background and the empirical results in the literature (see Sections 2.2 and 2.3.1) we expect capital stock (k_t), human capital (h_t) and ICTs (I_t) to have *direct* positive impact on the growth rate of the countries.

We also expect a positive direct effect of R&D on economic growth, particularly based on the theoretical arguments of new (endogenous) growth models (see Section 2.2 and 2.3.1). However, there seems to be empirical ambiguity with regards the impact of R&D on TFP. While some economists have found that R&D had significant positive impact on TFP and thus on growth performances of the economies (see for example, Coe and Helpman (1995)) other economists have found significant negative impact on TFP due to the uncertainty and ambiguity that R&D entails considering its nature (see for example, Cozzi and Giordani (2011)).

As mentioned before, the direct impact of openness on economic growth depends significantly on the nature of the traded good. For example, imported machinery or capital goods have statistically significant positive effect on growth of per capita income compared to other consumption goods. That is, importing higher quality intermediate goods with improved technologies enhances productivity of the economy.[40] Fagerberg and Srholec (2008) also indicate that in the empirical studies there is no or little support that openness (to trade) has on innovation and catching-up. Therefore, we do not have a priori expectations with regards openness.

Considering the indirect effects of knowledge indicators via the catch-up terms there is no clear cut answer with respect to the theoretical expectations. This is succinctly emphasized by the well known technology-gap theorists Jan Fagerberg and Bart Verspagen,

> Rather than a global public good, available to everyone for free, it became clear to observers that there were large technological differences (or gaps) between rich and poor countries, and that engaging in technological catch-up (narrowing the technology gap) was perhaps the most promising avenue that poor countries could follow for achieving long-run growth. But the very fact that technology is not a global public good, i.e., that such technological differences are not easily overcome, implies that although the prospect of technological catch up is promising, it is also challenging, not only technologically, but also institutionally (Gerschenkron, 1962) Fagerberg and Verspagen (2001: 2).

In our specification the technological gap or economic backwardness of countries are represented by the terms in brackets in Equation (2.15). Considering the above remarks by Fagerberg and Verspagen (2001), based on the ideas of Gerschenkron, while the higher gap size (economic backwardness) is promising, it can also become an obstacle if it is not handled properly by the governments (e.g. if they fail to create conducive institutional environment). Therefore, we do not have a priori expectations for the catch-up terms in Equation (2.15).[41]

As explained before, we also introduce the variables one by one into the empirical analysis before considering the full specification (Equation 2.15). For

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[40] See Frankel and Romer (1999) for more detail.

[41] Recall that the catch-up terms are interactive variables represented by the interaction of each knowledge indicator with the technological gap variable.

instance, Benhabib and Spiegel (1994) model's stochastic version is provided below;

$$\Delta y_{it} = \alpha_0 + \alpha_1 h_{it} + \beta_1 h_{it}\left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}}\right] + \gamma t + \phi i + \theta_1 \Delta k_{it} + \varepsilon_{it} \qquad (2.16)$$

where all variables are defined as earlier.

Similarly we introduce other knowledge variables into the analysis; for example, individual role of R&D stock in the catch-up process can be analyzed with the following stochastic version,

$$\Delta y_{it} = \alpha_0 + \alpha_2 R_{it} + \beta_2 R_{it}\left[\frac{Yp_{\max t} - Yp_{it}}{Yp_{it}}\right] + \gamma t + \phi i + \theta_1 \Delta k_{it} + \varepsilon_{it} \qquad (2.17)$$

where all variables are defined as earlier.

Now we will discuss the issues related to the estimation.

Due to the heterogeneity of countries there will be correlation between the independent variables (i.e. the assumption that individual effects should be uncorrelated with other independent variables is violated) the OLS estimates become inconsistent and suffer an upward bias. Therefore, to overcome this problem and considering other advantages of traditional panel data regression, that are explained below, Equation (2.15) and other specifications, such as Equation (2.16) and (2.17) are estimated with panel data regression (fixed effects) methods using balanced panel data from 34 OECD countries from 1995 to 2011.

Majority of the studies conducted in the related literature have utilized cross-section analysis, particularly during the 1990s. However, in this study panel data analysis is preferred over cross-section analysis because;[42]

i. panel data analysis assumes that countries are heterogeneous. Since the cross section studies do not control for this heterogeneity they run the risk of obtaining biased results.

ii. panel data simplifies computation and statistical inference. In panel data when time series data are not stationary[43] and observations among cross-sectional units are independent then the limiting distributions of many estimators remain asymptotically normal.[44] Panel data, with multiple observations for a given country or at a given time, helps us to overcome under identification problem resulting from measurement errors. That is, panel data gives more informative data and more variability.

iii. panel data are better at uncovering dynamic relationships.

iv. panel data has greater capacity for capturing the complexity of variables (in our case countries) than a single cross-section. Because it can also; uncover dynamic relationships; construct and test more complicated behavioral hypotheses; control the impact of omitted variables; identify and measure effects that are simply not detectable; and generate more accurate predictions for individual outcomes by pooling the data.

v. panel data has less multicolinearity among the variables, more degrees of freedom and more efficiency compared to cross section.

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[42] See Hsiao (2005 and 2006) for more detail.

[43] However, in this study we use macro panel data and hence extra care should be given for nonstationarity (we consider this issue in Section 2.5).

[44] See Binder et al. (2005), Im et al. (2004), Hsiao (2005 and 2006) and Levin et al. (2002) for more detail.

2.4.2. The Definitions and the Sources of Data

The main variables that are used in the model are output (Y), capital stock (K), human capital per worker (h), R&D stock (R), openness (O), and ICT term (I). While the former three are obtained from PWT 8, the others are from the WDI database.[45,46]

Output (Y) is the real gross domestic product (GDP) at current purchasing power parities (PPPs) (in million 2005 US$). For international comparison GDP is converted to international dollars using the PPP rates.

Capital stock (K) is the real capital stock measured at current PPPs (in million 2005US$). In the PWT 8 data, capital stocks are "estimated based on cumulating and depreciation past investments using the perpetual inventory method" (Inklaar and Timmer, 2013:5).

Human capital per worker (h) is obtained by calculating the index of human capital per person based on years of schooling (Barro and Lee, 2012) and returns to education (Psacharopoulos and Patrinos, 1994). Education is an important indicator of the capacity of the labor force to use the available information. Barro and Lee (2012) use a combination of data sources to infer the percentage of each country's adult population (aged twenty-five and older) the particular level of education they obtained for each year. Census data provide direct measures of a country's stock of education but, especially, in developing countries such data are only available for selected years. Barro and Lee (2012) use enrollment data and data on literacy rates to interpolate between census years to fill the missing data.

Labor (L) is represented with the number of persons engaged in employment (in millions).

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[45] The World Development Indicators (WDI) data set of World Bank and recent version (July 2013) of the Penn World Tables (PWT 8) are used in this study.

[46] It is important to mention that PWT 8.0 provides two set of data for capital and output as well as productivity for cross country comparison and for country specific analysis. Since this essay is based on a cross country comparison we use the data set relevant for our analysis. See Feenstra et al. (2015) and Inklair and Timmer (2013) for more detail.

Research and development Stock (R) is calculated based on the perpetual inventory method following Griliches (1980) (in million 2005US$). As underlined by Griliches (1980) and discussed in detail by Schankerman (1981) there are two important measurement problems when we use indicators such as research and development expenditure (% of GDP) as a proxy of R&D in our analysis. First, we face the problem of double counting because the conventional proxies of capital and labor include elements of R&D. For example, R&D workers are included in the labor force and also R&D investment is included in the total capital stock and the "failure to recognize the double-counting of R&D inputs and the expensing of R&D can be framed as an omitted variable problem" (Eberhardt et al. 2013:438). Secondly, in the value added calculation R&D is treated as intermediate expense. Thus, in order to avoid the problem of double counting and mutlicollinearity we have calculated the R&D stock for the OECD countries as follows,

$$R_{it} = (1-\delta)R_{it-1} + RE_{it} \tag{2.18}$$

where R_{it} is the R&D stock of country i at time t, RE_{it} is R&D expenditure of country i at time t and δ is the depreciation rate ($0 < \delta < 1$).

The depreciation rate is used as 0.15 following Griliches (1998) and Ruge-Leira (2015). The initial R&D stock (for 1995) is determined by following Ruge-Leira (2015). That is, the initial R&D stock is calculated as $R_{i,95}=RE_{i,95}/(g_i+\delta)$, where g is average growth rate of GDP of country i over 1995-2011 and as above δ is 0.15.

Openness (O) is measured by dividing total trade (exports plus imports) to GDP. It gives us information about the economic structure of the country, regarding the degree of integration to the world economy via foreign trade. That is, the share of trade (exports and imports) in GDP can viewed as an indicator of that countries level of globalization and competition in the global economy. Foreign trade is also a channel for knowledge spillovers across national borders. That is, trade is a mean to access foreign knowledge which is embedded in the traded goods. Sometimes the imitation of this acquired new knowledge may spur innovation that will enhance economic growth.

However, it should be noted that "[d]espite the overwhelming popularity of the simple trade ratio measure, researchers should be aware that this measure is a measure of country size and integration into international markets rather than trade policy orientation … [T]he five *least* open countries are (in order) Japan, Argentina, Brazil, the United States, and India ... While it is clear that these countries have trade restrictions in varying degrees, it is difficult to believe that they are the most restrictive countries in the world in terms of trade policies." (David, 2007:9).

Information and Communication Technologies (I). Telephone lines, internet hosts/active Internet Protocol (IP) addresses, mobile phones, personal computers are the variables used to capture the levels and the growth rates of ICT.

In this study we will use information "I" dimension of ICT and it is proxied by using fixed broadband Internet subscribers, which is measured on per 100 people basis for the entire country.

As indicated before this chapter utilizes a dataset formed by merging WDI data set and PWT data sets. The WDI provides various indicators, ranging from demographic to environmental topics and it contains more than 800 indicators for 214 countries for the years 1960 to 2012, compiled from officially recognized sources. Whereas the PWT provides 30 variables on purchasing power parity and national income accounts indicators for 167 countries for the 1950-2011 period.

The two datasets were matched at country level. Before matching the datasets first a country code key was developed. Prior to merging the two datasets 47 countries that did not have data in the PWT database and the data for the year 2012 were dropped from the WDI dataset, thus we lost 3052 observations.

Then by using with the country code key the two datasets was merged. Finally, only data for the 34 OECD member countries for the 1995-2011 period was kept. This is particularly dictated by the availability of data on R and I as well as the presence of newly established countries - after the breakdown of U.S.S.R. - in the OECD.

The descriptive statistics of the variables and the correlation between these variables are presented in Table 2.1 and Table 2.2, respectively.

The correlation matrix (Table 2.2) indicates that there is positive and moderate correlation between the growth rates of per capita capital stock and per capita output. There is also positive and a much stronger correlation between human capital and ICTs. The other positive and moderate correlation is between human capital and R&D stock. On the other hand there seems to be negative and moderate correlation between R&D stock and trade. The negative correlation between R&D stock and openness may possibly indicate that countries that lack the R&D capability to produce advanced technologies would import high tech products, this is not a surprising relationship. One unexpected result is the negative correlation between the per capita output growth and ICTs. The correlation between the rest of the variables are weak.

Nevertheless, even though information on correlation gives us an opinion on the nature and the strength of the relationship between two variables, it is worthwhile to mention that all these pair wise correlations are not substitute for an econometric analysis based on theoretical models. In the next section we will provide such empirical analysis.

2.4.3. Empirical Results

To analyze the relationship between knowledge indicators and economic growth we used panel data analysis as explained in Section 2.4.1. Due to the possibility of unobserved heterogeneity in the explanatory variables of our model and the possible correlation of the disturbance term with the explanatory variables, fixed effects estimator was used, to allow for a country fixed effect that is correlated with the determinants.[47] To control for autocorrelation and heteroskedasticity we used Huber/White or sandwich estimators and hence heteroskedasticity and autocorrelation robust (HAC) standard errors.[48]

In line with our empirical strategy as set out in Section 2.4, first we introduce each variable separately and then we estimate our fully specified model by introducing all knowledge indicators together to see their joint impact on growth rate of output per labor and catch-up effects. Regression results are provided in Table 2.3.

Table 2.1. Descriptive Statistics of the Variables

Variable	Definition	Obs	Mean	Min	Max	Std. Dev.
Growth Rate of Per Capita Output (Δy)	Log difference of real GDP per worker at current PPPs (in mil. 2005US$) [%]	578	1.596	-7.794	16.361	2.509
Growth Rate of Per Capita Capital (Δk)	Log difference of capital stock per worker at PPPs (in mil. 2005US$) [%]	578	2.222	-4.342	13.026	2.100
Human Capital (h)	Human capital per worker (based on years of schooling and returns to education)	578	3.006	1.978	3.6187	0.303
R&D Stock (R)	R&D Stock (in mil. 2005US$)	578	1.36×10^{11}	0.0035×10^{11}	23.2×10^{11}	3.46×10^{11}
Openness (O)	Trade (% of GDP)	578	87.715	16.749	333.5	49.883
Internet (I)	Fixed broadband internet subscribers (per 100 people)	578	42.075	0.082	95.020	29.127

47 The Hausman Test also supported our decision.

48 The option ‘robust’ in STATA helps us to obtain sandwich estimators.

As can be seen in Table 2.3, six models were estimated. Model 1 is the benchmark model with only one explanatory variable (capital stock). Model 2 is the Benhabib and Spiegel (1994) model that investigates the relationship between the growth rate of per capita output and growth rate of per capita capital and human capital stock (as well as its catch-up effect).

Model 3 to Model 5 contain both the direct and indirect (catch-up) effects of other knowledge indicators, albeit individually. The last model in Table 2.3, Model 6, is our fully specified technological catch-up model which includes all knowledge variables and their catch-up terms

Table 2.2. Correlation Matrix

	Δy	Δk	h	R	O	I
Δy	1					
Δk	0.3494*	1				
h	-0.0265	-0.0075	1			
R	-0.0417	-0.0984*	0.3301*	1		
O	0.0503	0.0215	0.1406*	-0.3438*	1	
I	-0.2849*	-0.1496*	0.4215*	0.1319*	0.1701*	1

Note: * p<0.05

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As can be seen from Table 2.3 the panel fixed effects estimations of all six models have serious problems. The first issue that draws our attention is that, with the exception of Model 6, growth rate in per capita capital is statistically insignificant in all models.[49] Another issue is that some signs of the estimated coefficients are not in line with our a priori expectations. For example, in Model 2 where we analyze the impact of human capital and its catch-up effect (Benhabib and Spiegel model) the human capital has a negative coefficient which is contradictory to our theoretical expectation.

[49] In Model 6, Δk is only significant at 10% level. Considering this anomaly, we also re-run the models by using the levels of y and k. The results are provided in Appendix 2.B.

Table 2.3. Results of Panel Data Analysis (Δy)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Growth Rate of Per Capita Capital (Δk)	0.2434	0.2049	0.2342	0.1972	0.2359	0.27160*
	[0.1487]	[0.153]	[0.1472]	[0.1554]	[0.1516]	[0.1522]
Human Capital (h)		-5.672***				-2.2147
		[1.419]				[2.2599]
Human Capital Catch-up (C_h)		0.5697***				-0.2126
		[0.1804]				[0.3044]
R&D Stock (R)			-0.000002**			0.000001
			[0.000001]			[0.000001]
R&D Stock Catch-up (C_R)			-0.00001			0.000012*
			[0.000007]			[0.000007]
Internet (I)				-0.023***		-0.022***
				[0.00353]		[0.0071]
Internet Catch-up (C_I)				-0.006419		-0.006406
				[0.00531]		[0.003894]
Openness (O)					-0.0177*	0.01835
					[0.0091]	[0.0118]
Openness Catch-up (C_O)					0.0201***	0.0175***
					[0.0031]	[0.0062]
Constant	1.06***	16.198***	1.6996***	2.269***	0.55659	5.6303
	[0.3305]	[4.34096]	[0.4019]	[0.43336]	[1.13496]	[6.5167]
Observation	578	578	578	578	578	578
R-squared	0.032	0.134	0.038	0.125	0.123	0.191
Countries	34	34	34	34	34	34

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

Similarly, all of the results of our panel data estimation, regarding the direct effects of knowledge variables, are either theoretically inconsistent or they are not statistically significant. In the fully specified model, all of the four direct effects are theoretically inconsistent or statistically insignificant and two of the catch-up terms are not statistically significant.[50]

Considering all these results there seem to be serious problems related to specification and estimation. Now we will discuss these issues.

- It is a commonly faced problem in dynamic panels where traditional panel data analysis, such as fixed effects model, fails to capture the dynamic nature of the time dimensions and the heterogeneity among the countries, regarding the dynamic adjustment.[51]

- In traditional panel data analysis it is assumed that some parameters (for example, slope parameters) are same across the panel, i.e. the pooling assumption. When this assumption does not hold, that is when we have heterogeneous panel, bias arises in both static and dynamic panels.[52] Another situation that results in inconsistent fixed and random estimators is when we have small T and large N, as in our case. Thus, when T is small and the dynamic panel data is biased we might end up with misleading results. Most commonly used alternative, to overcome the heterogeneity bias is the pooled mean group (PMG) estimator introduced by Peseran et al (1999).

- Considering the theoretical background of our model, the core knowledge variables such as human capital and R&D expenditure can play

[50] As explained in Appendix 2.B., empirical results with the level form specification are considerably better. But it should be noted that the level form specification does not have a similar interpretation with either our models or that of Benhabib and Spiegel's approach. Nevertheless, "better" results from the level form specification indicates the danger of differencing the level form relations like production function. That is, when nonstationary variables are differenced, valuable information is lost form the data (see Asteriou and Hall, 2011)

[51] See Asteriou and Hall (2011) for more detail.

[52] Peseran and Smith (1995) have proved that in these cases both fixed and random effects may be inconsistent.

different roles in different theoretical setups. For instance, human capital can play two different roles in endogenous growth models. While Lucas (1988) introduces human capital as an additional input and hence emphasizes human capital accumulation over time, Nelson and Phelps (1966) emphasize the role of human capital in adopting new technology and hence improving total factor productivity.[53] As we explained in Section 2.3 we have followed the approach by Nelson and Phelps (1966). However, in our above specifications (Models) we neglected the role of human capital accumulation in the growth process as emphasized by Lucas (1990). Additionally, in line with Griliches (1979) and Eberhardt et al. (2013), one can also include the other critical knowledge variables (e.g. R&D) as a shift factor in the production function without affecting the returns to inputs.

Therefore, in the following section, we will introduce a new (augmented knowledge) model and estimate it with PMG method, by considering all of the above mentioned issues.

2.5. An Augmented Knowledge Production Function: When Griliches Meets Lucas

As we explained in the introduction section one of the objectives of this chapter is to analyze the role of knowledge on OECD countries by developing an augmented knowledge production function.

In the previous section, we considered human capital as a factor in productivity however considerable empirical literature (e.g. Bosworth and Collins (2003), Senhadji (2000) and Inklaar and Timmer (2013)) consider human capital as an input (a la Lucas) in the production function. Therefore, by following those studies we consider the following production function with a skilled adjusted labor (human capital) input,

$$Y = A K^{\alpha} H^{\beta} \tag{2.19}$$

[53] Kruger and Lindahl (2001) provide detail discussion of these issues.

where Y is output (real GDP), K is capital stock and A is total factor productivity, H is human capital and it is also called adjusted labor input (H=hL, where h is human capital per labor and L is total employment).

Griliches (1979) emphasized that it is important to consider knowledge as an additional input to the traditional inputs, such as labor and capital, in the production function. More formally, he considers the following production function,

$$Y = f(L, K, R) \tag{2.20}$$

where L is labor and R is the R&D stock and the rest of the variables are as defined before.

Additionally, we also consider the role of ICTs and openness as important knowledge indicators in our model (see Section 2.2 and 2.3.1 for more detail).

Thus when we come Griliches's approach and Lucas's approach with our above argument on the role of ICTs and openness we can obtain an augmented production function. More specifically, we use the following Cobb Douglas production function,

$$Y = K^{\alpha} H^{\beta} R^{\gamma} C^{\phi} O^{\varsigma} \tag{2.21}$$

where C represents ICTs[54], O represents openness and all variables are defined as earlier.

[54] To avoid any confusion with panel data notation we choose to represent ICT with C rather than I, as has been used in the previous section.

Following Bosworth and Collins (2003) and Senhadji (2001) among others we impose constant returns to scale assumption (α+β=1) and hence we transform Equation (2.21) to per efficient worker form (Y/H and K/H) as follows,

$$\left(\frac{Y}{H}\right)=\left(\frac{K}{H}\right)^{\alpha} R^{\gamma}C^{\phi}O^{\varsigma} \tag{2.22}$$

where all variables are defined as earlier.

We obtain the following equation by taking the log of Equation (2.22)

$$\hat{y}_{it}=\alpha\hat{k}+\gamma r+\phi c+\varsigma o \tag{2.23}$$

where $\hat{y}=\ln\left(\frac{Y}{H}\right)$, $\hat{k}=\ln\left(\frac{K}{H}\right)$, r = ln(R), c = ln(C) and o=ln(O).

Therefore, in line with Griliches (1979) and Eberhardt et al. (2013) we included the knowledge variables as a shift factor in the production function without affecting the returns to inputs.

We re-state Equation (2.23) for empirical purpose in stochastic form as follows,

$$\hat{y}_{it}=\phi+\alpha\hat{k}+\gamma r+\phi c+\varsigma o+\varepsilon \tag{2.24}$$

where all the variables are as defined before, ϕ is constant term and ε is the error term.

Thus, the above (augmented) log linear production function can be thought as a long-run equilibrium relationship between factor inputs, knowledge variables and output.

Peseran and Smith (1995) argue that even though the dynamic specification is not common for all countries, in the long run the parameters might be common. Thus, they suggest

> either averaging the individual country estimates, or by pooling the long run parameters, if the data allows, and estimating the model as a system … [thus we can possess] the efficiency of pooled estimation while avoiding the inconsistency problem following from pooling heterogeneous dynamic relationships (Asteriou and Hall, 2011:436).

In the PMG estimator, only the long run coefficients are same across countries and the short run coefficients vary. For this exact reason, Bassanini and Scarpetta (2002) have used PMG estimators in their analysis of the long-run relationship between factor inputs and output in their sample of OECD countries over 27 years. Similarly, as noted by Eberhardt et al. (2013) the PMG estimators are preferable when we have small set of similar countries (as in the case of OECD) rather than large diverse macro panels. Furthermore, as underlined by Asteriou and Hall (2011) another critical advantage of the PMG is that "the parameter estimates are consistent and asymptotically normal for both stationary [I(0)] and non-stationary I(1) regressors" (Asteriou and Hall, 2011:427).

Thus, when we are analyzing group of countries such as the OECD, by following Peseran, Shin and Smith (1999), we may expect a common long-run equilibrium relationship. That is, we can estimate common long run coefficients for the augmented production function for the OECD countries. Therefore, following Peseran, Shin and Smith (1999) we use the following error correction model in our empirical analysis;

$$\Delta \hat{y}_{it} = \varphi_{it} + \omega_{it}\Delta \hat{k}_{it} + \zeta_{it}\Delta r_{it} + \psi_{it}\Delta c_{it} + \varpi_{it}\Delta o_{it}$$

$$+\lambda_i(y_{it-1} - \phi - \alpha k_{it-1} - \gamma r_{it-1} - \phi c_{it-1} - \varsigma o_{it-1}) + \varepsilon_{it} \tag{2.25}$$

where ω_{it}, ζ_{it}, ψ_{it} and ϖ_{it} are the short run parameters and λ_i is the error correction term. The term in the brackets represents the deviation from the long run relationship in the previous period.

It should be noted that while long run coefficients are same across (OECD) countries short run coefficients are allowed to vary. Hence

> "[t]he PMG method of estimation occupies an intermediate position between the MG method, in which the slopes and the intercepts are allowed to differ across countries, and the classical fixed effects method in which the slopes are fixed and the intercepts are allowed to vary" (Asteriou and Hall, 2011:436).

The alternative pooled estimates for the knowledge production function with no restrictions, Mean Group (MG), and with common long-run effects (PMG) are provided in Table 2.4.

As is seen from the last column PMG estimates of the production function is in line with theory and statistically significant. However, MG estimates are not consistent with the theory (in terms of signs and/or magnitudes of estimates) and statistically insignificant. The Hausman test statistic also prefers the PMG estimator. That is the efficient estimator under the null hypothesis (PMG) is not rejected.

According to our results (based on PMG estimates) a 1% increase in capital stock increases output per efficient worker by 0.28%. A 1% increase in R&D stock, ICT and openness increases output per efficient worker about 0.16%, 0.03% and 0.04%, respectively. Thus, according to the results of our analysis in the long run, knowledge variables, especially the R&D stock, seems to play an important role in the economic growth performances and catch-up efforts of OECD countries.

Table 2.4. Alternative Pooled Estimates of Augmented Production Function

	MG	PMG
Capital Stock ($\hat{k}$), α	2.06726	.27698***
R&D Stock (r), γ	-.90317	.15651***
ICT (c), ϕ	.01957	.02796***
Openness (o), ς	-.19542	.04446***
ecm, λ	-.78879***	-.36514***
Observations	544	544
Number of code	34	34
Hausman	[Prob>chi2= 0.9171]	

Finally, the sign and magnitude of overall error correction term (-0.36514) of the PMG estimates is in line with a priori expectations and it is statistically significant. This result implies that the OECD countries, taken together, converge to the common long-run equilibrium represented by the augmented knowledge production function. In other words, our results indicate that there is convergence among the OECD members in the long-run.[55]

2.6. Concluding Remarks

One of the widely used models in the economic growth and catch-up literature belongs to Nelson and Phelps (1966). In their seminal study Nelson and Phelps underlined the importance of human capital in adoption and imitation of

[55] In the previous model (the augmented catch-up model), due to the static nature of the model, the catch-up (interaction) terms were included to test the catch-up performance (convergence) of lagging countries. However, in this new set-up due to the structure of the error correction models catch-up (or convergence) enters the model directly via the error correction term.

technology. Later this model was taken once step further by Benhabib and Spiegel (1994) who introduced the catch-up term to analyze the role of human capital in the catch-up efforts of follower countries.

In the theoretical part of our study we wanted to take Benhabib and Spiegel's study another step further and analyze the impact of knowledge variables on economic growth and catch-up performances of follower countries. In our model we included four knowledge variables (human capital, R&D expenditure, ICTs and trade) such that they have two effects on a countries' total factor productivity. Firstly, they can improve the ability of a follower country to use and improve imported technology. Secondly, these knowledge indicators as a whole determine the speed of catch-up of the follower countries.

We carried a multi-country empirical analysis for OECD countries using panel data from 1995 to 2011 to analyze the relationship between knowledge indicators and economic growth by employing traditional fixed effects model. However, the results of our econometric analysis contradict our theoretical expectations. That is, majority of the results of our panel data estimation, both the direct effects of knowledge variables and the catch-up terms, are found to be either theoretically inconsistent or statistically insignificant.

When we further investigated as to why we ended up obtaining such controversial results to our a priori expectations, we found that there were serious limitations with the specification used by Benhabib and Spiegel who have followed the Nelson and Phelps' specification.

In their model Nelson and Phelps emphasize the role of human capital in adaptation/using new technology and hence improving total factor productivity. Thus, human capital enters the model via total factor productivity. In our specification we have also followed Nelson and Phelps and introduced our knowledge indicators (including human capital and R&D stock) into the model through total factor productivity.

However, as underlined by Lucas (1988) when human capital enters the model as an additional input it captures the role of human capital accumulation in the growth process. Following Lucas (1988) in our new model we introduced human capital as an additional input together with capital stock and also included the other critical knowledge variables as a shift factor in the production function (as suggested by Griliches (1979) and Eberhardt et al. (2013)). We named this new production function as the augmented knowledge production function.

In contrast to Benhabib and Spiegel's (1994) static panel data analysis we also utilize dynamic panel data techniques which are more suitable for macro panel data. Our new framework also utilizes the long-run information in the data by focusing on the equilibrium relations. This was not possible with the previous analysis based on Benhabib and Spiegel approach which focused on the differenced form of production function which looses the valuable long run information. Following, Peseran et al. (1999) we used PMG estimator where only the long run coefficients are same across countries and the short run coefficients vary. One advantage of PMG method is that it takes into account non stationary cointegration that is commonly observed in macroeconomic analysis with panel data where there is large number of countries over short period of time. Considering the aim of this essay another advantage of this framework is that in this new set-up convergence or catch-up efforts can be tested directly, i.e. by testing the significance of the error correction term.

The results of the PMG estimation of our new production function were both theoretically and statistically significant. That is, our analysis of 34 OECD countries for 1995-2011 period, indicates that knowledge variables as a whole have positive impact on the economic growth performances of OECD countries and they seem to be converging to the common long-run equilibrium represented by the augmented knowledge production function.

CHAPTER 3

THE ROLE OF KNOWLEDGE ON ECONOMIC GROWTH:THE CASE OF TURKEY, 1963-2010

Although the impact of knowledge on economic growth is an important topic, it has not been investigated thoroughly for the Turkish economy. When the studies on the role of knowledge in economic growth performance of Turkey are analyzed, to the best of our knowledge, majority of them are descriptive and/or review articles.[56] Most of the empirical studies on the relationship between knowledge and the economic growth of Turkey focus on the role of a single or specific dimension or pillar of knowledge (for example, education or R&D)[57] on economic growth. Without any doubt, these studies attempted to provide useful insights on the role of specific dimensions of knowledge on economic growth, however considering the multidimensional structure of knowledge as a whole, unfortunately, they are not sufficient either in terms of empirical analysis or data or scope. Therefore, a more efficient analysis would be to use a production function framework to see the overall effect of various pillars of knowledge -education, R&D, ICTs and openness on economic growth of Turkey.

This chapter analyzes the impact of knowledge on economic growth in Turkey over the 1963-2010 period by using a production function approach. In doing so popular time series methods, such as cointegration and impulse response analysis, were used to analyze the role of knowledge on economic growth in Turkey. In contrast to early studies, which have analyzed the impact of a single dimension of knowledge on economic growth we construct a knowledge

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[56] For example, Saygılı (2003), Kelleci (2003), Çakmak (2008), Kibritçioğlu (1998) and Uçkan (2006).

[57] See, for example, Kar and Ağır (2004), Özsoy (2009) and Şimşek and Kadılar (2010).

index that helps us to see the impact of various dimensions of knowledge with a single and comprehensive measure of the "level" of knowledge in the economy. As we shall explain later, this approach (construction of a single measure) also has a methodological advantage due to the presence of severe multicollinearity among the knowledge indicators.

The following section introduces the developments in the Turkish economy during the 1960-2010 period, then Section 3.2 presents the literature survey and Section 3.3. introduces our model. Section 3.4 provides the knowledge index, Section 3.5 provides the empirical results and finally, Section 3.6 provides the concluding remarks.

3.1. Main Developments in the Turkish Economy during the 1963-2010 Period

In this section we will analyze the developments in the Turkish Economy during the last five decades.

Without any doubt the most profound event in the Turkish Economy during this period has been the shift from import substitution led development strategies to export oriented development strategies, in 1980. Thus, we will analyze the developments in the Turkish economy by dividing it into two main periods; the import substitution period (1963-1979) and the export/outward oriented period (1980 onwards).

During the first period (1963-1979), in order to catch up with the industrialized countries, like most of the developing countries, Turkey implemented import substitution led development strategies. The State Planning Organization (SPO) had started to prepare[58] five year development plans and annual programs, which outlined the main goals and strategies in the process of

[58] The SPO (currently Ministry of Development) is still preparing five year plans which lack their previous powers and aspirations (Ekinci, 2000:2).

development.[59] In these plans and programs main emphasis was given to the manufacturing sector and the lion share of the public investment was transferred to this sector. Another important sector was the agricultural sector which was implicitly supported via support purchases.[60]

The growth performance of the Turkish economy during the 1960s was quite impressive (see Figure 3.1). Additionally, Turkey registered low levels of inflation rate during this period (see Figure 3.2). However, the domestic economic instability[61] combined with the two oil shocks of 1970s, showed its impact on the Turkish economy. From mid-1970s onwards inflation became the dominant characteristic of the Turkish economy (Figure 3.2). Apart from the monetary factors[62] the main source of inflation was the deficit of public sector[63] (it was financed by the central bank[64]) which is also regarded as one of the leading sources of the debt burden experience. During the late 1970s, this debt burden turned into debt crisis (Celasun and Tansel, 1993:273) and hence negatively affected economic growth (see Figure 3.1). By 1980 it was evident that the import substitution policy was insufficient to accommodate economic growth and Turkey was trapped in economic instability.[65] In 1980 with the support of IMF and World Bank Turkey adopted a comprehensive stabilization and adjustment program. The switch from import substitution policy to the export oriented policy was one of the key elements of the 1980 program. The

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[59] For more detail see Celasun and Rodrik (1989).

[60] This is also regarded as one of the causes of inflation in 1970s (see for example, Celasun and Rodrik (1989)).

[61] Increasing public debt burden, inflation and so on.

[62] For example, money and exchange rate.

[63] For example, during the 1963-1977 period the public sector accounted for 50-55% of the total investment in the economy (Celasun and Rodrik, 1989:626).

[64] See Lim and Papi (1997) for more detail.

[65] The instability during the late 1970s was mainly due to the debt and the severe balance of payment crisis. See, Celasun and Rodrik (1989) and Ekinci (2000) for more detail.

main impact of this policy until mid-1980s was an increase in aggregate saving and decrease in domestic absorption (Celasun and Tansel, 1993:273).[66]

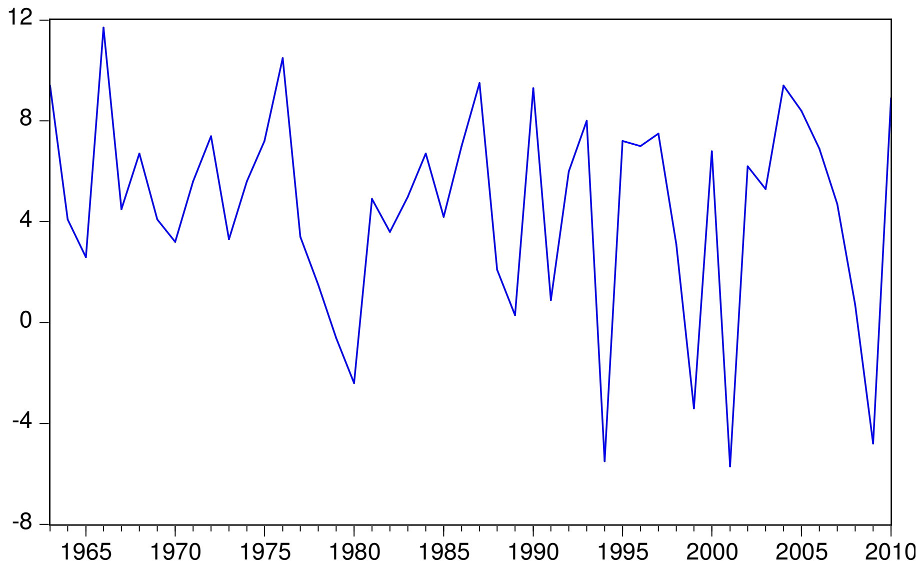

Figure 3.1. Growth Rate of Real GDP (%)

During the early 1980s, Turkey was somewhat successful in lowering inflation rate and increasing economic growth rate (see Figure 3.1 and 3.2). In mid-1990s, once again, Turkey experienced chronic inflation rate (see Figure 3.2) mainly resulting from excessive domestic borrowing, debt mismanagement and populist policies of governments. In 1994 Turkey entered into financial crisis and the inflation rate reached to its peak (three digit) level.[67]

Hence, Turkey implemented an IMF based stand-by agreement in 1994 and by 1995 succeeded to reduce the inflation rate to two digits. Mainly due to populist policies and political instability Turkey had failed to take the

[66] Turkey experienced a military intervention in 1980 which has lasted until the end of 1983.

[67] For more detail on the 1994 crisis see Celasun (1998), Ekinci (2000) and the references therein.

necessary precautions and actions to overcome the same problems[68] during the 1990s that she had been facing since mid-1970s. Even though it was too late for adjustment, the last coalition government nevertheless signed a new stabilization program with the IMF but could not avoid entering a severe economic crisis in 2001. Along with the structural problems of the IMF program, the institutional weaknesses of the banking sector is seen as the main cause of the crisis in 2001 which was the most severe economic crisis in the Turkish economy (its GDP shrunk by 5.7%).[69]

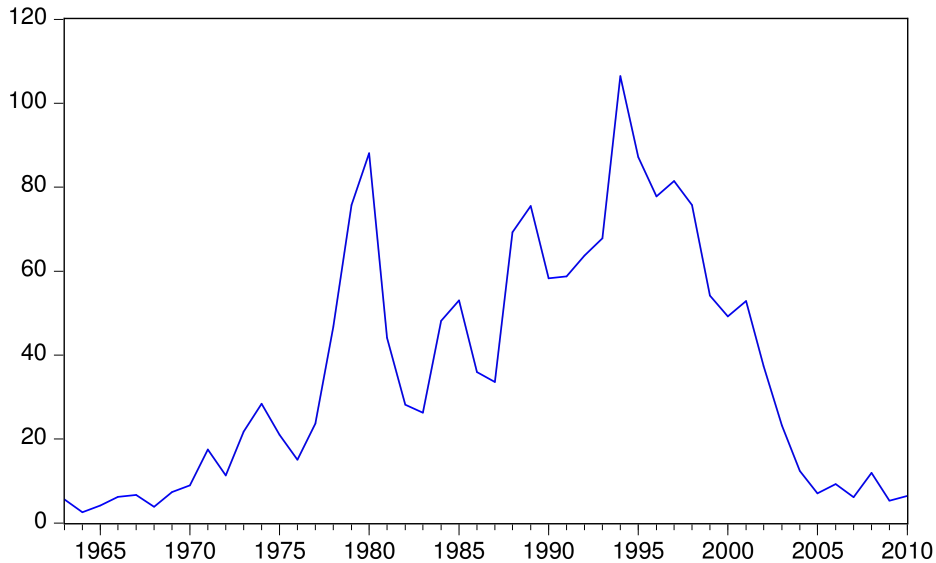

Figure 3.2 Inflation Rate (%-age change in GDP Deflator)[70]

Turkey signed a redesigned stabilization program with IMF right after the crisis in February 2001.

[68] Inflation, inefficient public finance and debt burden.

[69] See for example, Ozatay and Sak (2002), Ozkan (2005) and Yeldan (2002) for more detail.

[70] Source: SPO (Ministry of Development).

The successful implementation of the new IMF stabilization program, along with reforms, positive developments in relationships with the EU, inflation rate has decreased from high and chronic level of roughly 60-70% in 1990s to a single digit inflation rate during the post 2004 period (see Figure 3.2). As a result of this normalization in the economy the growth rate of the Turkish economy has increased at an impressive rate during 2002-2006 period (see Figure 3.1). Nevertheless, this growth performance has not been sustained due to excessive reliance on short term capital inflows which resulted in chronic current account deficit.

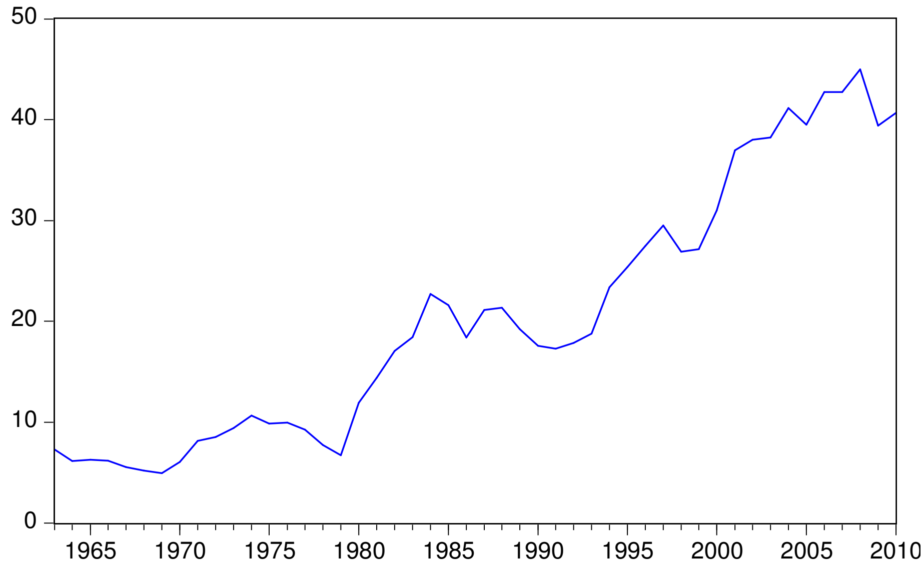

Figure 3.3 Trade-to-GDP Ratio (%)[71]

However, it should be underlined that even though the macroeconomic policies implemented during the early 2000s has contributed to decreasing economic instability and high level of economic growth this had a transitory impact (see Figure 3.1). Even though there has been sharp increase in foreign trade during the end of the 20th century (especially after 1996 when the customs union

[71] Source: See Section 3.5 for the details on the data.

agreement with the European Union entered into force) and beginning of the 21st century (see Figure 3.3), its contribution to the Turkish economy has been limited. In other words the accelerated rate of increase in imports compared to the rate of increase in exports has made Turkey dependent on foreign resources and worsened its current accounts and thus has made it vulnerable to external shocks. As a result, Turkey has been influenced by the latest global crisis in 2008/9 and experienced a significant decrease in growth rates (see Figure 3.1).

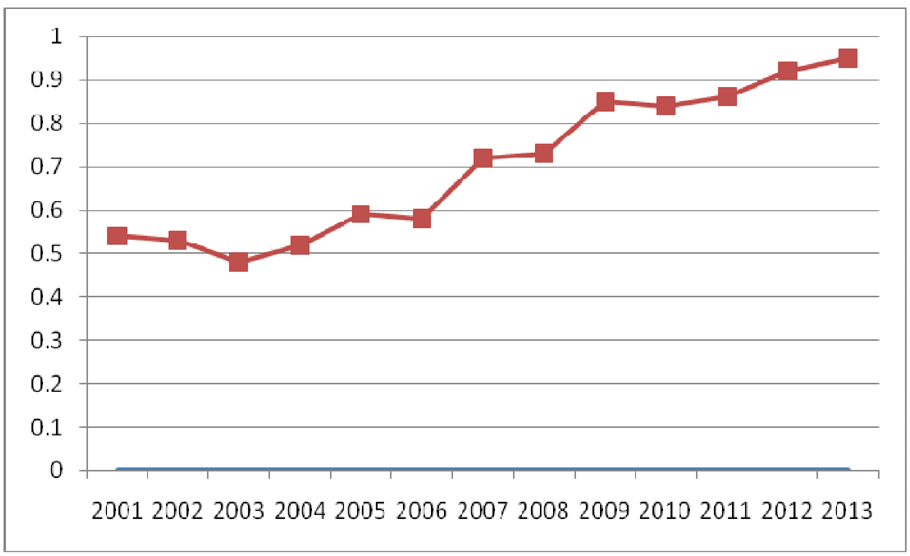

Figure 3.4 Share of R&D in GDP (%)

Finally, it should be noted that research and development and innovation policies have been in the agenda of the Turkish policy makers since 1960s.[72] As seen in Figure 3.4, even though the share of R&D in GDP has slightly increased from 0.5% (2001) to 0.94% (2013) (way below the EU average of 3%) there have been some important steps taken to enhance R&D activities and

[72] Appendix 3A provides a comprehensive overview of the developments in science technology and innovation policies in Turkey.

funds allocated to R&D during the last decade. During this period Turkey has shown considerable effort to increase R&D activities. The aim, as clearly indicated in the 2023 national strategy, is to further increase the share of R&D expenditures in the national income to 3% by 2023.

3.2. Literature Review

In this section we will provide a review of the prominent growth theories starting with the Solow model (1956), the exogenous growth model, which is considered as the building block of the modern growth theory.[73] However, in line with the aim of this chapter we will focus on the endogenous growth models with particular emphasis on the pillars of knowledge. Thus, in this section first we will introduce the exogenous (Solow) growth model and then examine the endogenous growth models and the relevant empirical evidences.

3.2.1. The Exogenous (Solow) Growth Model

The neoclassical growth theory is based on production functions which are characterized by strict neoclassical assumptions. That is, in many neoclassical models the production functions exhibits constant returns to scale, diminishing returns to inputs and there is the perfect competition assumption which ensures that the firms are price takers. According to this model economic growth performance of a country was influenced by an exogenous factors, namely, technology[74] and population growth.[75] Solow (1956) had considered

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[73] However, it should be mentioned that the modern growth theory has evolved from studies that have introduced new aspects or criticisms to the classical growth theory that dates back to Malthus. In the classical growth theory there is a subsistence level and the real gross domestic product (GDP) growth is always temporary. During the early 20th century Harrod (1939) and Domar (1946) have tried to introduce Keynesian aspects to economic growth theory. In contrast to the classical economy, in these models the economy does not reach full employment and stable growth rates naturally.

[74] Technology is available and accessible for every single country in the world free of charge because it is “manna from heaven”, i.e. public good.

[75] Technology enters the production function as a residual of total factor productivity, i.e. the Solow residual.

technology as exogenous variable and had simply postulated that time was the only variable that affected the level of productivity (or productivity). That is, the exogenous technology term was added to allow for long-run growth in GDP per capita. He used the following aggregate production function:

$$Y = A(t)\, F(K, L) \tag{3.1}$$

where Y is the level of aggregate output, K is the level of the capital stock, L is the size of the labor force, A is total factor productivity and t is time.

In the long run, it is assumed that the GDP per capita of all countries grow at the same, exogenously determined rate. In other words, the most important prediction of the exogenous growth models was that poorer countries due to their higher grow rates would eventually converge to the growth levels of richer countries. But in reality, rather than converging, the growth gap between the poor and rich increased. For example, while the rich countries grew at an average rate of 2.5% per year during the 1960-2004 period, the developing countries, with the exception of East Asian Countries, has had disappointing growth rate especially since 1980 (see Rodrik (2007) for more detail).[76]

Since the mid-1980s, economists argued that endogenous factors within the economies were the factors that determined the economic growth rate and such divergence of growth performances will be explained in the following section.

3.2.2. Endogenous Growth Models

Lucas (1988) and Romer (1986) stressed the importance of knowledge (particularly human capital) and technological progress in economic growth

[76] For instance, especially the Latin America and Caribbean countries and sub-Saharan African countries have grew less than 1% since 1980.

performance of countries.[77] They modified the production function by adding human capital along capital and labor. In this framework the human capital has been recognized as the most important factor that influenced performance of the richer countries. Most importantly, human capital is considered to be the key input in R&D which accelerates technological progress (Romer, 1990). Investment in R&D in the richer countries is seen as the primary cause of technological progress (or innovations) which improved the capital goods (machinery or other intermediate inputs) used in the production process. Thus this new strand of growth theory by internalizing technological progress tried to explain the growth rates of countries. The assumptions, in general, are more flexible and more realistic compared to the neoclassical models. There is increasing returns to scale and in some sectors of the economy there is imperfect competition. Other issues such as policy decisions, the role of state and trade have entered into growth theory through endogenous growth models.[78]

Below, therefore, the endogenous models based on human capital, research and development, government spending and new trade theories are presented.

Endogenous Models Based on Human Capital

As mentioned previously, in their seminal papers, Arrow (1962), Nelson and Phelps (1966) and Uzawa (1965) introduced the ideas of education and learning by doing into the literature. Therefore, these authors could be considered as the forerunners of the endogenous growth models. Nelson and Phelps (1966), for instance, argued that education speeded up technological diffusion simply because educated human resource was much faster in

[77] Initially, with their seminal papers Arrow (1962), Nelson and Phelps (1966) and Uzawa (1965) drew attention to the importance of education and learning by doing for economic growth.

[78] The improvements in the mathematical techniques have also made it possible for economists to abandon the assumption of perfect competition and work with imperfect competition.

adopting the new technology. According to some economists this was the main factor behind the East Asian Miracle.[79]

The production function can be written broadly as follows:

$$Y = A(h)\,F(K, L) \tag{3.2}$$

where h is the stock of human capital and all other variables are as defined earlier.

During the late 1980s, while retaining the neoclassical perfect competition assumption Romer (1986) has stressed the importance of knowledge and Lucas (1988) has stressed the importance of human capital. Romer introduced knowledge as the key factor that caused long-run growth and increasing returns to scale.[80] Therefore, considering the above arguments of the forerunners Romer (1986) has enlarged the concept of capital by including investment in knowledge alongside accumulation of capital goods. Knowledge in this case is a public good which is available to every single firm.

Lucas (1988) separated the effects of human capital into two groups; the internal and the external effects. The production function in this case consists of accumulated physical and human capital and both inputs exhibit constant returns to scale.

The production function, without the externality effect, can be written as follows:

$$Y=AK^{\beta}\,[uhL]^{(1-\beta)} \tag{3.3}$$

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[79] See for example, Collins and Bosworth (1996), Chen (1996), Nelson and Pack (1999) and Barro and Lee (1994) for more detail.

[80] However, some economists (for example, Sala-i-Martin (1990b)) argue that increasing returns to scale is not necessary to generate endogenous growth.

where u is the fraction of time that individuals devote to work (non-leisure), h is the average quality of workers and L is the number of workers (uhL is the human capital) and all other variables are as defined earlier.

The internal effects (due to the learning by doing during the training process) and the external effects are spillovers of knowledge, where individuals tend to learn more when they work with more qualified people.[81]

With the inclusion of externalities the production function becomes

$$Y = AK^{\beta}[uhL]^{(1-\beta)}\, h^{\alpha}_{a} \tag{3.4}$$

where all variables are as defined earlier. In this production function uhL is the total effective labor used during the production of the output and the externality enters in the form of average (quality) human capital (h^{α}_{a}).

Lucas (1988), rather than focusing on the effects of investment has concentrated on the intentional accumulation of knowledge. In this case building a human capital has expenses, but it is also considered as an asset with a financial return.[82] It is assumed that there are infinitely lived households where stock of human capital is passed from the present generation to the future generation. Just like Romer's model, the positive external effects of knowledge are acknowledged and it is treated as a public good. Thus, human capital in these models is the main accelerator of economic growth.

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[81] Similar argument had been made by Nelson and Phelps (1966) who argued that educated managers would much easily integrate new technologies into the production process.

[82] Therefore, the externality introduced in this model explains migration.

Endogenous Growth Models Based on Research and Development

The seminal contributions of Romer (1990), Grossman and Helpman (1994), and Aghion and Howitt (1992)[83] have specified the R&D sector as the growth engine of the economy. The R&D sector establishes innovations and new products or ideas on new product/production techniques, for the other sectors in the economy. It uses human capital and accumulated knowledge to produce new knowledge. The technological spill-overs are important and the accumulated public knowledge contributes to the productivity of the R&D sector. New knowledge (or innovation) is used in the production of new products or production techniques and it also increases the total stock of knowledge and the amount of individuals employed in the R&D sector. The innovator in this set-up has been given some property rights on the blueprints but does not have any rights on the way this innovation is used in further research. In other words, the innovator has been given some temporary monopolistic rights on this new innovation to cover for the investment that has been made, this is a reflection of the Schumpeterian idea.[84] So, the argument in this strand of the literature is that monopolistic power (and hence profits) emerges as the essential motivation behind the innovational activities.

According to the *first-generation R&D growth models*, the long-run rate of economic growth is proportional to the total amount of research undertaken in the economy. In these models, the rate of economic growth is permanently influenced by an increase in the number of researchers employed in the R&D sector. Jones (1995) criticized this prediction by arguing that the rate of total factor productivity (TFP) growth had remained constant in advanced countries despite the increase in R&D expenditure. This argument led the way to the *second generation growth models* without scale effect.

[83] Romer (1990), Barro and Sala-i-Martin (1990) and Grossman and Helpman (1991) are the seminal studies in this strand of endogenous growth literature.

[84] The Schumpeterian idea indicates that new innovations are motivated by the possibility of obtaining profits.

One strand of the second generation growth models, known as the semi-endogenous growth models,[85]argues that economic growth is characterized by weak scale effect. That is, the level of steady-state per capita income is an increasing function of the size of the economy, but not its growth rate. Because, as argued by Solow, the long-run rate of economic growth is determined by the exogenous rate of population growth.

The other strand of the second generation growth models are known as "Schumpeterian" fully-endogenous growth theory.[86] This strand of second generation models support the predictions of first generation growth models that a permanent increase in the number of R&D workers permanently influences the rate of economic growth. However, unlike the first generation models, in this case, policy measures effect the rate of economic growth over the long run without the scale effect.

Cameron et al. (2005) in their analysis on the productivity growth in United Kingdom manufacturing industries between 1971 and 1992 have found that R&D raised the rate of innovation. Similarly, Harhoff (1998) in his study on 443 manufacturing firms in Germany R&D's impact on productivity finds a positive and significant result only for high-tech firms.[87] Üçdoğruk (2009) found that the smaller firms had higher R&D intensity and foreign ownership had no significant effect on R&D intensity in her analysis on the effect of size on R&D intensity.

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[85] See, for example, Jones (1995), Kortum (1997) and Segerstrom (1998).

[86]See, for example, Aghion and Howitt (2008), Dinopoulos and Thompson (1998), Peretto (1998) and Young (1998).

[87] However as Kalaycı (2012) underlines "… there is inconclusive evidence in the case of developing countries whether R&D has any effect or any positive significant effect on productivity, particularly when taking the technological opportunities of different industries into account" (Kalaycı, 2012:76).

When we consider the empirical findings, in addition to the above mentioned factors other factors such as the type of the R&D expenditure (Falk, 2007)[88] and government incentives have proven to affect the successful outcomes in developing countries (Castellani and Zanfei, 2006).

Özçelik and Taymaz (2008) and Taymaz and Üçdoğruk (2009) have found that government support programs for R&D together with technology transfers encourage private R&D investment and has a positive significant effect on R&D intensity. However, the harmony between government policies is essential for a successful outcome. For example, Pamukçu and Erdil (2011) found that if foreign capital policies and R&D policies are not in harmony and do not complete each other, this negatively influences the foreign R&D capital investment, as is the case in Turkey.

<u>Endogenous Growth Models Based on Government Spending</u>

The seminal works of Barro (1990) and Barro and Sala-i Martin (1990) have emphasized government investment as an essential factor for economic growth. They argued that investments of governments both on human capital (e.g. education) and on infrastructure (e.g. telecommunications, roads and electricity) are necessary for economic growth. Considering the experiences of the developing countries, one cannot help but agree with this argument. To develop a sufficient level of absorptive capacity, it is essential to invest in infrastructure and human capital.[89]

In these models the government services which accelerate the productivity of the private capital is incorporated within the production function. Barro (1990) model assumes that some of the goods that are used in production process are private goods provided publicly. Another important assumption of the model is

[88] For example, the industrial expenditures in general have more impact on the long run economic growth and factor productivity (see, Bassanini et al. (2001), Coe and Helpman (1995) and Nadiri (1993)).

[89] See, for example , Smeets (2008) for more detail.

that when government expenditure and capital are used together the production function exhibits constant returns to scale, but on the other hand when they are separately considered there is diminishing returns.

The Cobb-Douglas specification of the aggregate production function of the Barro (1990) model is as follows:

$$y = Ak^{(1-\alpha)}g^{\alpha} \tag{3.5}$$

where g represents government services and all other variables are as defined before.

In this model, the government has to balance its spending and the only source of government income is assumed to be income tax and it is also assumed that the society takes the government spending as given. One of the most important implications of this strand is the argument that, the government expenditure which is financed via taxes is distortionary in the long-run.

Endogenous Growth Theory and the New Trade Theory

Grossman and Helpman (1989) with their seminal study have underlined the importance of international trade and the trade policy for economic growth. They argued that engaging in liberal trade activities, made it easier for the developing countries to transfer stock of knowledge and increase participation of foreign direct investments. In 1991, Grossman and Helpman (1991)[90] introduced an open economy framework and argued that countries could acquire foreign technology through imports because imported goods embodied technological know-how.

[90]Coe and Helpman (1995) in their study on developed countries found that domestic and foreign R&D had significant impact on total factor productivity (TFP).

Another implication of this strand of endogenous growth theories is that trade would be more beneficial for larger countries, because, compared to small countries they can make much better use of economies of scale and invest on R&D activities more than the developing countries. Cameron et al. (2005) in their analysis on the United Kingdom manufacturing industries found that international trade enhanced the speed of technology transfer. Hasan (2000) in her study on Indian manufacturing firms for the ten years from 1977 to 1987 found that imported technologies (both embodied and disembodied) had positive impact on productivity. Meshi et al. (2011), found positive effect of R&D expenditure and foreign technology on skill upgrading.

Madsen (2007) found a robust relationship between imports of technology and TFP, and that 93% of the increase in TFP over the past century has been primarily due to imports of knowledge for the OECD countries over the period 1870 to 2004.

Moreover, other economists[91] have found positive impact of different knowledge diffusion channels, such as trade and FDI, on the growth rates of countries.

3.2.3. Endogenous Growth and the Primacy of Knowledge

Chen and Dahlman (2004), based on the endogenous growth models, postulated that economic and institutional regime, educated and skilled population, dynamic information infrastructure and efficient innovation system are the four main pillars (or preconditions) of knowledge economy which transforms knowledge into an effective engine of growth. They argue that when these four pillars are strengthened this would increase the accumulation of quality knowledge used in production, and thus increase economic growth via affecting total factor productivity (TFP).

[91] See, for example, Wang (1990), Wang and Blomstrom (1992), Eaton and Kortum, (2001) and Glass and Saggi, (2001) for more detail.

Chen and Dahlman (2004) suggested the following production function framework for the analysis of the role of knowledge on economic growth,

$$Y = A(g, e, r, i)\, F(K, L) \tag{3.6}$$

where g represents institutional and/or economic regime of the economy, e represents education and training, r represents country's level of domestic innovation, i represents country's information and communication infrastructure and other variables are as defined before.

It is worth to emphasize that the knowledge indicators (of the four pillars) affect the output growth via total factor productivity (A).

Considering the above arguments of Chen and Dahlman (2004), it seems to be worthwhile to construct a single indictor for measuring the various dimensions of knowledge. Later on, based on Knowledge Assessment Methodology (KAM) the World Bank developed the Knowledge Economy Index (KEI), as well the Knowledge Index (KI), for ranking countries. The KI is basically the simple average of the normalized performance scores of a country on the key variables; education and human resources, the innovation system and the ICT (i.e. as can be seen from Figure 3.5 they are the three knowledge pillars).

Without any doubt the KI is useful in providing a general snapshot regarding the positions and rankings of countries in terms of their overall knowledge base. However, the drawback of KI is the limitation in the availability of all the variables for a long time period (the KI is available for 2002-2012 period).[92]

[92] There is a serious skepticism about its ability to fully capture the actual knowledge levels of countries. As can be seen from Figure 3.5 each pillar consists of a large number of knowledge economy indicators. Considering the differences in the level of incomes of countries it is impossible for all of them to invest in all of the indicators. In general countries select the pillar of knowledge that they are investing based on their expected contribution to their economic growth and their available financial resources. See Sundać and Krmpotić (2011) for more detail.

Thus, the KI does not reflect the reality for most countries (especially the low and lower middle income group). Thus, this chapter introduces a single measurement that is capable to capture the knowledge indicators for a longer period.

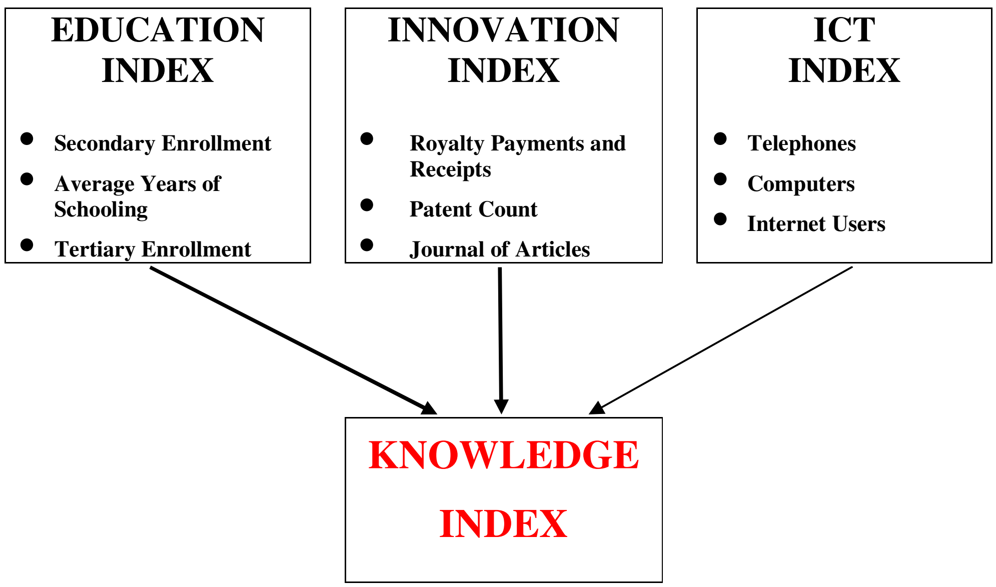

Figure 3.5 Knowledge Index[93]

3.2.4. Empirical Findings on the Role of Knowledge on Economic Growth of Turkey

Majority of the studies on the role of knowledge in economic growth that are conducted in Turkey are descriptive and/or review articles.[94] Furthermore,

[93] The figure has been prepared by the author using information in KAM (2012) (www.worldbank.org/kam).

most of the other (empirical) studies are, unfortunately, not sufficient either in terms of empirical analysis or data or scope. For example, majority of the empirical studies on the relationship between knowledge and the economic growth of Turkey focus on a single or specific dimension of knowledge; for example, the role of human capital (education)[95] and R&D.[96] For example, Kar and Ağır (2004) have found that improvement in human capital (measured as the share of education expenditures in GDP) during the 1926-1994 period had a positive impact on the long-run economic growth performance of Turkey. Similarly, Bozkurt (2010) in her empirical analysis analysing the relationship between education, health and economic growth for the 1980-2005 period in Turkey has found that these two factors had positive impact on economic growth performance of Turkey.

Ağır (2010) in his comparative analysis of Turkey and South Korea tried to find out the reason as to why there is wide gap between the two countries that had similar economic indicators up to 1970s. He finds that the determinant stand of the South Korean policy makers on science and technology policies has contributed to their research and development (R&D) and thus economic growth.

Yumuşak and Bilen (2010) based on the low performance of Turkey[97] in various indices developed by the World Bank, underline the importance of ICT, health and especially education investment in order to be a part of the information economy.

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[94] See, for example, Saygılı (2003), Kelleci (2003), Çakmak (2008), Kibritçioğlu (1998) and Uçkan (2006).

[95] See, for example, Kar and Ağır (2004), Özsoy (2007) and Şimşek and Kadılar (2010).

[96] See, for example, Yaylalı et al. (2010)

[97] Turkey ranked 61st (among 145 countries) in the information economy index, 74th in the information index, 44th in the economic and institutional regime index, 55th in the innovation index, 75th in the information and communications index and 87th in the education index (in 2009).

3.3. The Model

In this section we attempt to develop an augmented production function model by considering the strands of endogenous growth models on knowledge as explained above.

The following Cobb-Douglas production function is used -as the initial specification- in our empirical investigation of the role of knowledge on economic growth.

$$Y_t = \beta_0 O_t^{\beta_1} E_t^{\beta_2} P_t^{\beta_3} C_t^{\beta_4} K_t^{\beta_5} L_t^{\beta_6} \tag{3.7}$$

where O represents the economic structure (regime) of the economy, E denotes education, P represents country's level of domestic innovation and C denotes country's communication infrastructure, Y_t is output, K_t is capital and L_t is labor.

It should be noted that TFP (At) is explicitly modeled in Equation (3.7), and equals to $\beta_0 O_t^{\beta_1} E_t^{\beta_2} P_t^{\beta_3} C_t^{\beta_4}$.

Equation (3.7) can be restated in log-linear model as follows

$$LnY_t = \beta_0^* + \beta_1 LnO_t + \beta_2 LnE_t + \beta_3 LnP_t + \beta_4 LnC_t + \beta_5 LnK_t + \beta_6 LnL_t \tag{3.8}$$

where β_0^*=Ln β_0 and β_i's represent the respective elasticities (e.g. β_5 is the elasticity of output (Y) with respect to capital (K)).

Equation (3.8) allows us to investigate the role of the four dimensions (indicators) of knowledge on growth (that is, the role of openness, education, country's level of domestic innovation and country's communication infrastructure) as mentioned in Section 3.2.3. However, these four indicators are highly correlated (see Section 3.4); therefore, we attempt to construct a proper knowledge index (KNIW). As mentioned before, construction of such an index provides us a single but comprehensive measure on the "level" of knowledge in the economy, which has multi-dimensional facets (see, for instance, World Bank, 2006). Thus, considering all these issues, equation (3.8) can be re-written as follows,

$$LnY_t = \beta_0^* + \theta\, KNIW_t + \beta_5 LnK_t + \beta_6 LnL_t \tag{3.9}$$

where KNIW is the knowledge index[98] and all the other variables are as defined earlier.

In line with the literature (for example see Chen and Dahlman (2004)) constant returns to scale is imposed on Equation (3.9) and we obtain the following specification.

$$y_t = \beta_0^* + \theta\, KNIW_t + \beta_5 k_t \tag{3.10}$$

where y_t [= ln(Y/L)] is the natural log output per labor, k_t [=ln(K/L)] is the natural log physical capital per labor and KNIW is the knowledge index.

We will use the following empirical (stochastic) log-linear model in the empirical applications.

$$y_t = \alpha_0 + \alpha_1 KNIW_t + \alpha_2 k_t + u_t \tag{3.11}$$

where u_t is the disturbance term and all other variables are as defined earlier. Note that $\alpha_0=\beta_0^*$, $\alpha_1=\theta$, $\alpha_2=\beta_5$.

[98] Details of the knowledge index are provided in Section 3.4.

Considering the growth models and their implications (see Section 3.3) we expect positive signs for k_t and $KNIW_t$ ($\alpha_1 > 0$ and $\alpha_2 > 0$). In other words, we expect to see an increase in broad level of knowledge (KNIW) and capital per labor (k) to have positive effect on output per labor (y).

From here onwards our empirical analysis proceeds in two steps. First we construct the knowledge index in the next section. Then we estimate the production function provided in Equation (3.11) in Section 3.5.

3.4. The Knowledge Index

In the previous section the main determinants of knowledge were introduced as the economic structure (regime) of the economy, education, level of domestic innovation and communication infrastructure to our (augmented) production function framework. In our empirical analysis they are proxied with foreign trade to GDP ratio (O), average years of schooling (E), total patent applications (P) and total number of telephone subscribers (C), respectively. The choice of these indicators are mainly dictated with the availability of data. More detail regarding measures, definitions and the choice of data are provided in Section 3.5.1.

As noted before, construction of a knowledge index would provide us with a single and comprehensive measure on the "level" of knowledge in the economy. Moreover, such an index could also prevent the potential problem of multicollinearity in the empirical analyses, particularly with the time series data, since as mentioned before the indicators of knowledge economy are highly correlated (Table 3.1). As can be seen from Table 3.1 the coefficient of correlation between our variables is significantly very high.[99]

[99] The correlation between openness (LNO) and domestic innovation (LNP) (0.68) is moderate but it is still significant.

The knowledge index (that will be referred to as KNIW from here onwards) is basically the average of normalized indicators (sub-indices) for each of the four dimensions.

Table 3.1. Correlation Matrix of the Knowledge Indicators

	LNC	**LNP**	**LNE**	**LNO**
LNC	1.000000	0.780799	0.988333	0.955331
LNP	0.780799	1.000000	0.718296	0.680130
LNE	0.988333	0.718296	1.000000	0.967248
LNO	0.955331	0.680130	0.967248	1.000000

The procedure of calculating KNIW is summarized in Figure 3.6. So far the dimensions (pillars) of KNIW and the indictors that will be used to proxy each dimension have been determined. Now we will explain the details of the calculation of each dimension index (sub-index) for every single dimension of knowledge.

Since the four dimensions of knowledge are in different units and have different ranges (minimums and maximums), the Human Development Index (HDI)[100] methodology is used to obtain a common range for them. That is, a minimum and a maximum bound is set to each of the four indicators and a number (index value) is obtained for each of these indicators between 0 and 1. After this conversion all of the raw variables turned into unit free indices, between 0 and 1, that can be compared or used together.

[100] See UNDP (1990) for more detail.

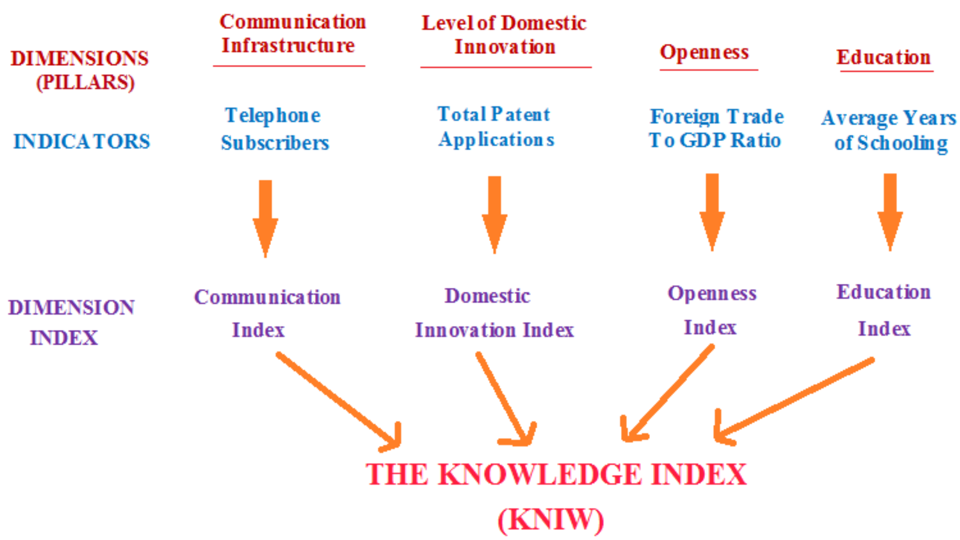

Figure 3.6. Calculation of KNIW

In sum, with this transformation the four indicators become dimension indices which are labeled as ILNC, ILNP, ILNE and ILNO. The four dimension indices are calculated as follows:[101]

$$ILNC_t = \frac{LNC_t - Min(LNC)}{Max(LNC) - Min(LNC)} \tag{3.12}$$

$$ILNP_t = \frac{LNP_t - Min(LNP)}{Max(LNP) - Min(LNP)} \tag{3.13}$$

$$ILNE_t = \frac{LNE_t - Min(LNE)}{Max(LNE) - Min(LNE)} \tag{3.14}$$

[101] Since in our log-linear model (Equation 3.8) C, P, E and O entered in log (ln) form we used these variables in our calculations in log form as well.

$$ILNO_t = \frac{LNO_t - Min(LNO)}{Max(LNO) - Min(LNO)} \tag{3.15}$$

where LNC_t, LNP_t, LNE_t and LNO_t represents (natural) log of foreign trade to GDP ratio, log of average years of schooling, log of total patent applications and log of total number of telephone subscribers, respectively. Min (X) is the minimum value and Max (X) is the maximum value of variable X during the time interval (1963-2010) that is being investigated. The minimum and maximum values of each variable during the 1963-2010 period is presented in Table 3.2.

Table 3.2. The Minimum and Maximum Values of Variables (1963-2010)

	LNC	LNE	LNP	LNO
Minimum Value	12.20332	0.84587	6.23637	1.59919
Maximum Value	18.23827	2.04083	8.15880	3.80682

For example, the minimum value for the communication index was observed in 1963 (0) and the maximum value was observed in 2008 (1). Thus, in those years our indicator (C) contains the minimum and maximum values the following calculations provide the details;

$$ILNC_{1963} = \frac{12.2033 - 12.2033}{18.2382 - 12.2033} = 0$$

$$ILNC_{2008} = \frac{18.2382 - 12.2033}{18.2382 - 12.2033} = 1$$

The value for any other years is in between these two extremes, for example, the value of the communication index in 2000 is;

$$ILNC_{2000} = \frac{17.3575 - 12.2033}{18.2382 - 12.2033} = 0.8541$$

The time plots of all four dimension indices (ILNC, ILNP, ILNE and ILNO) are provided in Figure 3.7.

After normalizing the indicators and obtaining the dimension indices next we calculate the Knowledge Index (KNIW) as a weighted average of the four sub-indices, as follows:

$$KNIW = w_1\ ILNC + w_2\ ILNE + w_3\ ILNP + w_4\ ILNO \tag{3.16}$$

where w_i's denote weights of the respective dimension indices.

HDI used simple average methodology to determine the weights of each dimension index simply because all three dimensions were considered to be equally important.[102] However, rather than using the simple average methodology following Alesina and Perotti (1996) among many others, principal component analysis was used to determine the weights of each dimension.[103]

[102] That is, the three dimension indices (Life expectancy index, Education index and GNI index) were considered to have equal weights (1/3 each).

[103] Principal components analysis basically takes the high dimensional data and then uses the dependencies between the variables to represent it in a lower dimensional form, with minimum loss of information.

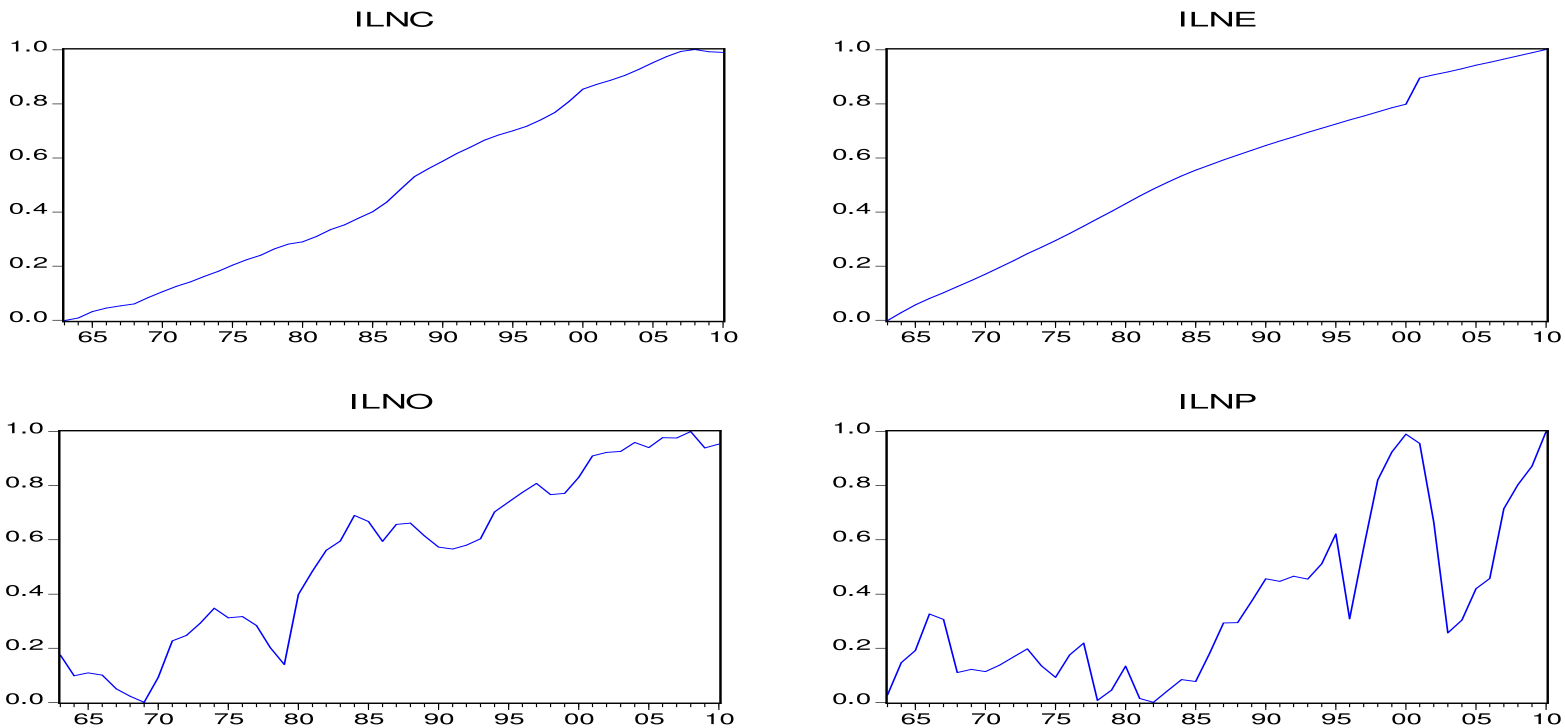

Figure 3.7. The Plot of the Dimension (Sub) Indices

Principal component analysis results are shown in Table 3.3. These results indicate that the first principal component (Comp 1) explains a high proportion of the variance (89%) in the data. The rest of the principal components have very low explanatory power in terms of explaining the variance in the data. Therefore we use the first principal component to calculate the respective weights for our index.

Table 3.3. Principal component Analysis

	Comp 1	**Comp 2**	**Comp 3**	**Comp 4**
Eigenvalue	3.559614	0.392161	0.041368	0.006857
Variance Prop.	0.889903	0.098040	0.010342	0.001714
Cumulative Prop.	0.889903	0.987944	0.998286	1.000000
Eigenvectors:				
Variable	**Vector 1**	**Vector 2**	**Vector 3**	**Vector 4**
ILNC	-0.525308	0.120199	0.456715	-0.707824
ILNE	-0.519244	0.276525	0.410120	0.696937
ILNP	-0.441353	-0.883181	-0.126428	0.095994
ILNO	-0.509553	0.359274	-0.779249	-0.063629

Nevertheless, as can be seen from Table 3.4, the principal component analysis has yielded practically similar results as the simple average methodology.[104]

Finally, by using the results of the principal component analysis presented in Table 3.4, KNIW is constructed as follows:

[104] Similar result was found by Nguefack-Tsague et al. (2010).

$$KNIW = 0.2633\ ILNC + 0.2602\ ILNE + 0.2212\ ILNP + 0.2554\ ILNO \qquad (3.17)$$

where all the variables are defined as before.

Table 3.4. Weights Determined by Principal Component vs. Simple Average

Variables	Principal Component Analysis [Relative Weights (w_i)]	Simple Average Analysis [Equal Weights (w_i)]
ILNC	0.2633	0.25
ILNE	0.2602	0.25
ILNP	0.2212	0.25
ILNO	0.2554	0.25

As can be seen from Figure 3.8 the time plot of the knowledge index of Turkey, during the 1963-2010 period, indicates that over the years there has been a steady increase in the level of knowledge of Turkey.

In sum, the knowledge index (KNIW) is a composite of the four sub-indices which roughly captures the four main dimensions (pillars) of knowledge. Therefore, the KNIW shows the level of knowledge in a given time period. As a consequence, KNIW gives us the possibility to analyze performance of Turkey, in terms of the attainment of knowledge over time. For example, if Turkey has a higher KNIW value in the current year compared to the previous year, then we may say that there has been improvement in the knowledge level. Nevertheless, it should be noted that some components (ILNO and ILNP) of the KNIW are sensitive to economic conditions (for example, economic crisis).

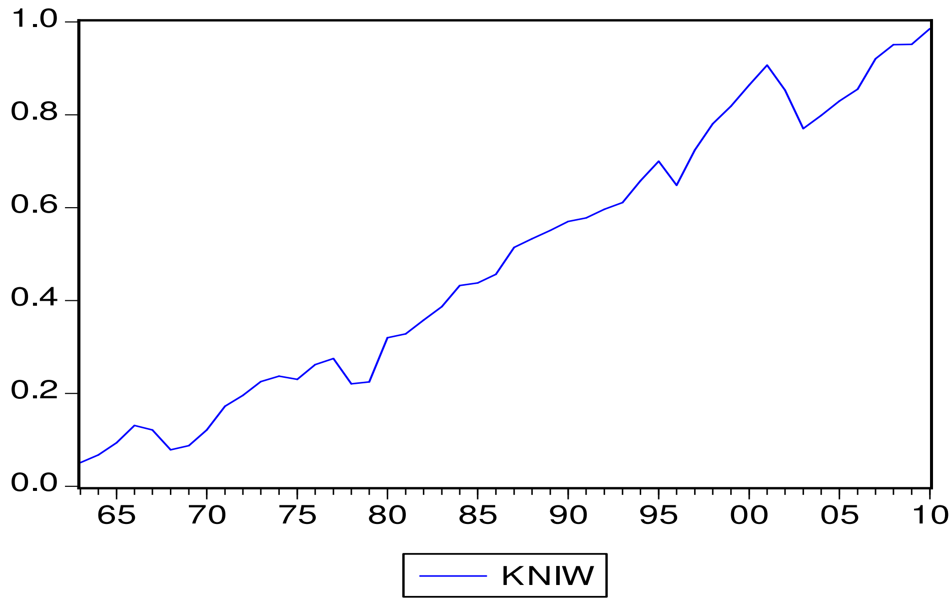

Figure 3.8. KNIW Index of Turkey, 1960-2010

3.5. The Data and the Empirical Results

3.5.1. The Data

Output (Y) is measured by Gross Domestic Product (GDP) at 1998 constant prices. The Turkish Statistical Institute (TurkStat) has provided a new GDP series (at 1998 prices, billion TL) from 1998 onwards. The Turkish State Planning Organization (SPO)[105] extended the series back to 1950s.

Capital Stock (K_t) is constructed based on the perpetual inventory method[106], that is,

[105] Ministry of Development.

[106] See, for example, among many others, Bosworth and Collins (2003) and Altuğ et al. (2008).

$$K_t = (1-\delta) K_{t-1} + I_t , \quad (3.18)$$

where I_t is gross fixed capital investment and δ is the depreciation rate ($0 < \delta < 1$).

TurkStat has recently changed the definitions of investment series (I_t) for 1998-2010 period and Saygılı and Cihan (2008) extended it back to 1948. In accordance with various studies (see for example, Bosworth and Collins (2003)) we have set the depreciation rate at 5% (δ =0.05). Initial capital stock is calculated in line with Altuğ et al. (2008).[107] It should be noted that the estimated capital stock series is at 1998 constant prices.

Labor (L) input is measured by employment data. TurkStat uses a broad definition for employed persons. Employed persons are "persons engaged in any economic activity during the reference period for at least one hour as a regular employee, casual employee, employer, self employed or unpaid family worker; all self-employed and employers who have a job but not at work; regular employees with a job who did not work if they have an assurance of return to work within a period of 3 months or if they receive at least 50% of their wage or salary from their employer during their absence; and apprentices or interns who are working to gain any kind of benefit are considered to be employed" (TurkStat, 2014). The employment statistics are yearly and given in thousands.

Since TurkStat provides employed persons only from 1988 onwards, for 1963-1988 period, following Saygılı and Cihan (2008) and Altuğ et al. (2008) we use the data series in Bulutay (1995).

Foreign trade to GDP ratio (O) is used as an indicator of the openness that has been followed by Turkey. It is calculated as the ratio total foreign trade to GDP (i.e. (export+import)/GDP). The data is obtained from TurkStat. According to one (trade) strand of endogenous growth models (see Section 3.3) openness is

[107] The initial capital stock is calculated as $K_{49}=I_{50}/(g+\delta)$, where g is average growth rate of GDP over 1950-2010.

favorable to economic growth hence we consider it as an indicator of knowledge.

Education (E) is measured by the average years of schooling of the labor force (age 15-64). We used the series in Altuğ et al. (2008) and extended this series to 2010. Altuğ et al. (2008) have used the data on educational attainment by gender and age groups that are available at five-year intervals through General Population Censuses. They have used survival rates by gender and five-year age groups to depreciate the educational stock. Then they construct the human capital series by multiplying the number of persons that are alive and the particular school they completed with the years of education required for that degree.

As been thoroughly explained in previous sections, education has the most important impact on the economic growth performances of countries. Thus, we expect education to have positive and statistically significant impact on the growth performance of Turkey. We, therefore, choose to include this variable as a knowledge indicator (proxy for) human capital in our analysis (particularly in our knowledge index).

A Country's Level of Domestic Innovation (P) is measured by using proxies such as patent and R&D expenditure. As Smith (2005) underlines the number of patents is a common proxy used because it is easy to measure and the patent data is easy to access. Moreover, the time span of the patent applications is longer than R&D data, therefore, we have selected the patent as a proxy for the domestic innovation variable and used the series of World Bank (WDI).

Park and Ginarte (1997) conducted a cross-national analysis of economic growth and patent rights. They found that general property rights have a positive and statistically significant effect on economic growth. Hu and Png (2013) also investigated whether patent rights fostered innovation and economic growth in 54 manufacturing industries of 72 countries between 1981–2000 period. They found that stronger patent rights were associated with faster growth in more patent-intensive industries, and the effect was larger in higher-income countries. Thompson and Rushing (1999) in their study for 55 on both developing and developed during 1975-1990 period have found positive relationship between patent and economic growth. Thus, in line with these studies we also expect patents to have positive and statistically significant impact on the growth performance of Turkey and hence we also consider this indicator as a proxy for the domestic innovation dimension of knowledge.

Total number of telephone subscribers (C) including mobile phone subscribers, is used to represent communications infrastructure. The data on telephone subscribers are obtained from the TurkStat and Telecommunications Authority.

When analyzing the impact of ICT on economic growth in a long time dimension some researchers use ICT product/measure methodology due to data constraints. That is they take one of the dimensions of ICT (e.g. IT (hardware/software), data communication (internet/broadband) and telecommunication (telephone or mobile)) in their analysis.[108] Due to similar constraints, following Correa (2006) and Röller and Waiverman (2001) we use telecommunication dimension (telephone subscribers) to determine the impact of ICT on economic growth. Both of these studies confirmed a positive and significant effect of ICT on productivity.

In sum, considering the data limitations we only considered the telecommunication sub-dimension as a proxy for communications infrastructure (as a pillar of knowledge).

3.5.2. Unit Root Tests

Before estimating the production function with the yearly time series data from 1963 to 2010, it is essential to check for the presence of a unit root in each

[108] See Kretschmer (2012) for more detail.

series. Figure 3.9 provides the time plots of y_t [=ln(Y/L)], k_t [=ln(K/L)] and KNIW. There is a visual evidence of nonstationarity in each series (Figure 3.9).

Table 3.5 provides the unit root test results. Both ADF and DF-GLS[109] tests yield similar results. As is clear from this table, for the levels of all the variables, the null hypothesis of a unit root is not rejected at the 5% significance level, including only constant term in deterministic components of the tests. Furthermore, the null hypothesis of a unit root for the first differences of all variables is rejected at the 5% significance level. Considering these results, it can be stated that all variables contain a unit root. However, if we consider unit root results with the inclusion of linear trend as a deterministic component, the null hypothesis of a unit root -for the levels of all the variables- is not rejected at the ***1%*** significance level but rejected at the 5% significance level for y_t and $KNIW_t$**.** Therefore, there is some evidence of the existence of deterministic (linear) trend in these two variables. Fortunately, Johansen cointegration method is capable for handling this empirical issue.

Nevertheless when we apply the Zivot and Andrews (1992) test to the data we found unit roots with possible breaks at 1975, 1979 and 1996, respectively for y, k and KNIW. Therefore we will also analyze the effect of structural change in those years as well as in 1980 considering the developments in the Turkish economy.

3.5.3. Cointegration Analysis

We use Johansen cointegration analysis (Johansen, 1995) for investigating the long-run relationship between knowledge and output (growth).[110] Considering the possibility of linear trends in data and following Hendry and Juselius (2001),

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[109] The Elliott-Rothenberg-Stock (ERS) DF-GLS tests (Elliott et al.,1996) are considered to be better (i.e. more powerful) than ordinary ADF tests (see for example, Zivot and Wang (2006) and Enders (2010)).

[110] Johansen approach is more efficient than the Engle-Granger approach in the case of more than two variables.

the deterministic components of the VAR model is specified as constant term entering unrestrictively and with no trend term in the cointegration relation.

Johansen cointegration tests; namely the Trace and Max tests suggest one cointegration relation among the three variables in Equation (3.11) (see Table 3.6). Table 3.6 also provides the normalized cointegration vector.

Johansen method estimated the production function in Equation (3.11) as follows:[111]

$$y_t = 4.1910 + \underset{(0.1418)}{0.5914} \; KNIW_t + \underset{(0.0708)}{0.3974} \; k_t \qquad (3.19)$$

where standard errors are presented in brackets.

Equation (3.19) implies that the output per labor is positively affected by both physical capital per labor and knowledge index. These findings are statistically significant and consistent with theoretical expectations.[112]

[111] Considering the sample size, lag length of the VAR is chosen as 1. Residuals of the equations of vector error correction (VEC) model are not serially correlated and homoscedastic at 5% and satisfy normality at 1% level of significance. After examining the residuals plot of the equations, we also re-performed the analysis by including an impulse dummy for 1994, to account for the significant economic crisis. In this case (including 1994 impulse dummy), residuals are not serially correlated, homoscedastic and normal at 5% level of significance. Estimated equation is quite similar to that of equation (3.19).

[112] Appendix 3B provides the sensitivity analysis of the main cointegration analysis provided in this section with respect to the various structural changes suggested by Zivot and Andrews (1992) test (see Section 3.5.2) as well as structural change due to policy change in 1980. Appendix 3C checks the robustness of individual indicators of knowledge and then introduces them together to the model for the sake of sensitivity.

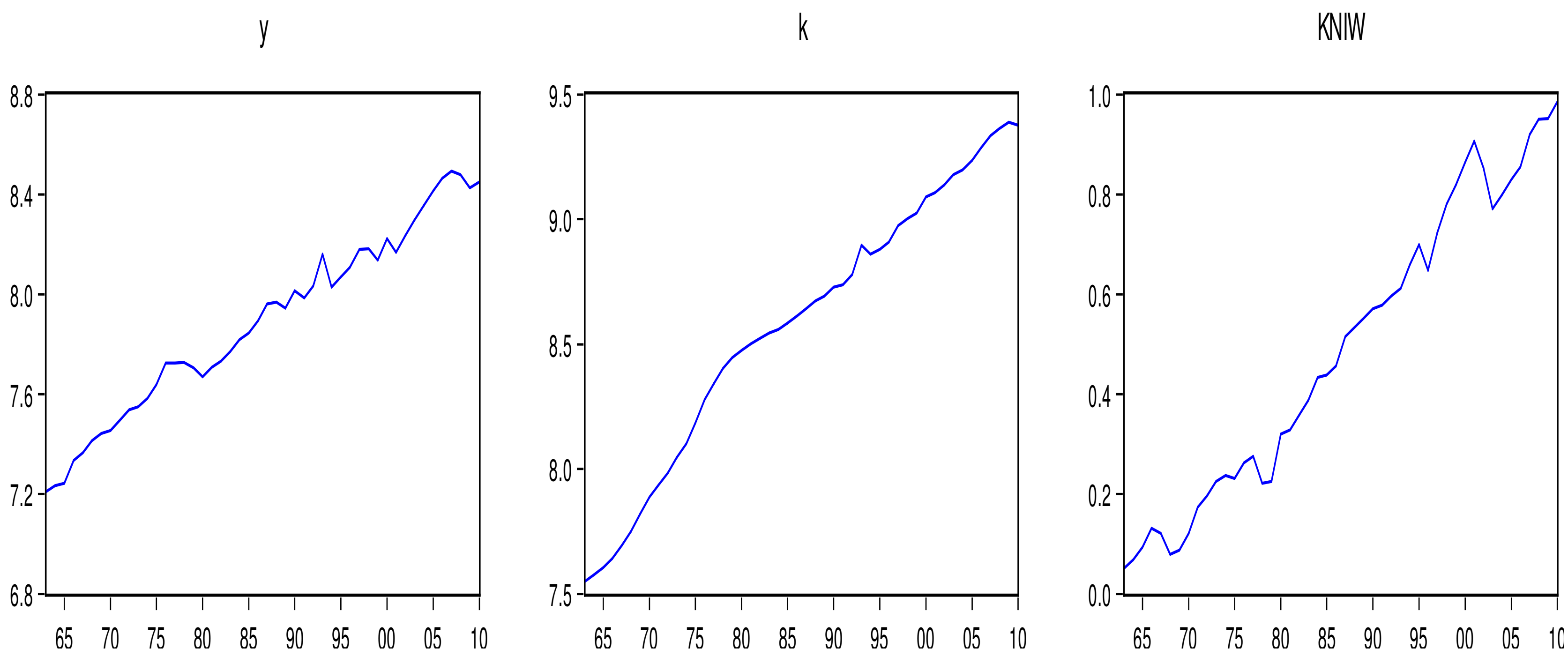

Figure 3.9. The Time plot of the data, 1963-2010

Table 3.5. Unit Root Tests

Variables	ADF Test			DF-GLS Test		
	Level		First Difference	Level		First Difference
	Without Trend	With Trend	Without Trend	Without Trend	With Trend	Without Trend
$\mathbf{y_t}$	-1.0704 (0) [a]	-3.6344 (0))* [b]	-8.2537 (0)*	1.1518 (0)	-3.4266 (0)* [b]	-8.3375 (0)*
$\mathbf{k_t}$	-2.4703 (0)	-1.0787 (0)	-5.2510 (0) *	-0.2111 (2)	-0.8158 (0)	-5.6709 (0)*
$\mathbf{KNIW_t}$	0.01832 (0)	-3.6023 (1) *	-5.9158 (1) *	1.6291 (0)	-3.3598 (1)*	-5.9842 (1)*

[a] The optimal lag chosen by SBC (Schwarz Bayesian Criterion) are given in parentheses. The maximum lag length is 2. SBC is recommended by ERS (1996) for selecting lag length (Also see Enders (2010:241)). [b]The asterisk indicates the rejection of null hypothesis (i.e. the existence of unit root) at the 5% significance level.

Fully Modified Least Squares (FM-OLS) method (Philips and Hansen, 1990) provided similar results:[113]

$$y_t = 4.0134 + \underset{(0.1567)}{0.4731}\ KNIW_t + \underset{(0.0857)}{0.4244}\ k_t \tag{3.20}$$

where standard errors are presented in brackets.[114]

Table 3.6. Johansen Cointegration Analysis Results

Cointegration Tests			
Eigenvalue	0.416716	0.117626	0.021231
Null Hypothesis	r = 0	$r \leq 1$	$r \leq 2$
Trace Statistic	32.22694*	6.890156	1.008623
Max-Eigen Statistic	25.33679*	5.881533	1.008623

Cointegration Vector

y_t	k_t	$KNIW_t$	Constant
1	-0.3974	-0.5914	-4.1910

Note: r denotes cointegration rank (the number of cointegration relation). The * indicates the rejection of null hypothesis at the 5% significance level.

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113 The FM-OLS approach takes into consideration the endogenity problem and non-stationary of the data (Philips and Hansen, 1990). Finally, note that the OLS method has provided quite similar results but unsurprisingly the estimates are not as close as the estimates of Johansen and FM-OLS techniques.

114 Newey-West standard errors are used. Residuals are normal.

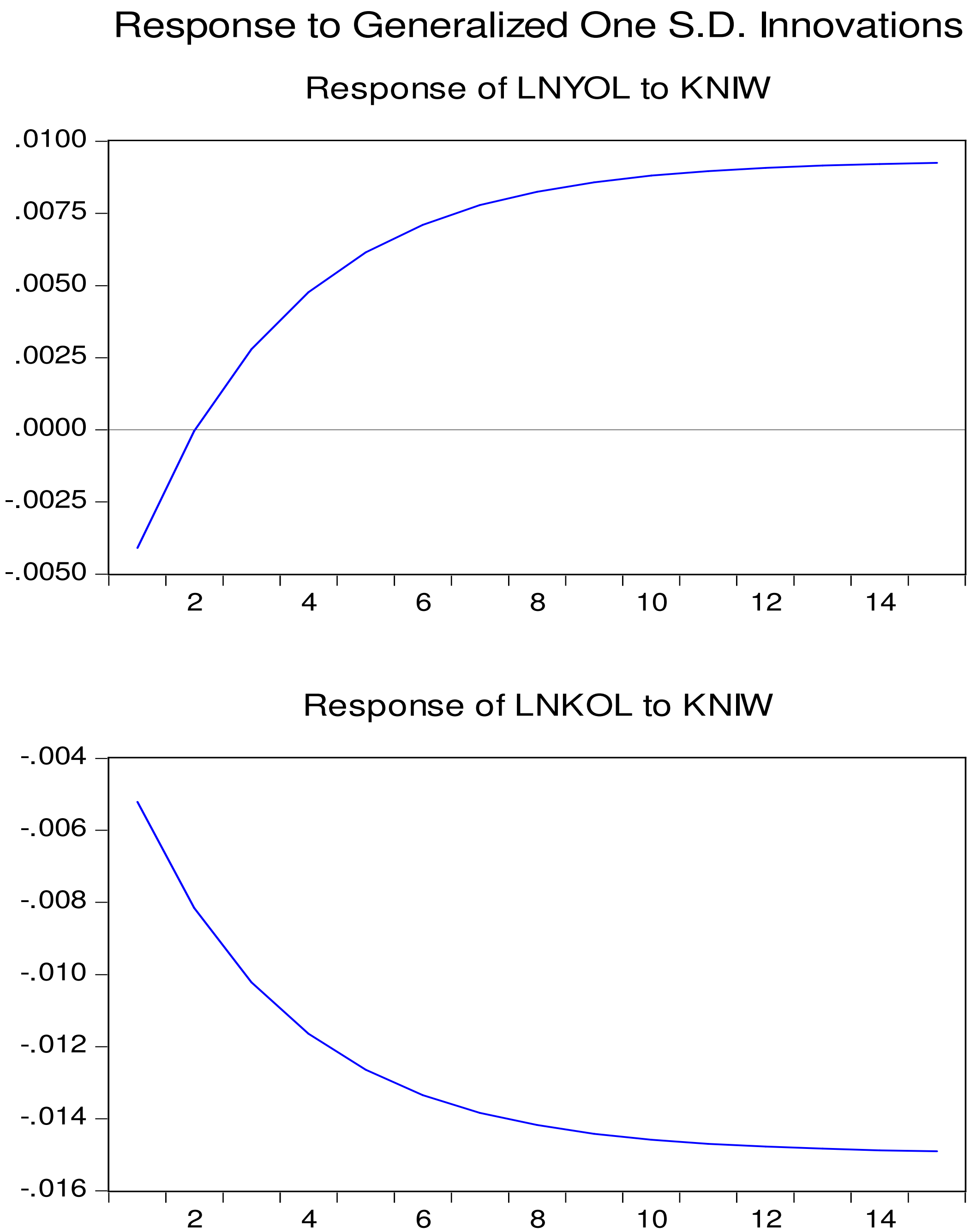

Figure 3.10 Impulse Responses to KNIW

As before, these findings are statistically significant and consistent with theoretical expectations.

Both Johansen and FM-OLS methods yield similar estimates for Equation (3.11) and they are consistent with the theory. Thus, we can confidently conclude that knowledge has a positive impact on the Turkish economy during the 1963-2010 period.

3.5.4. Impulse Response Analysis

In order to investigate the short-term dynamics of the production function model, this section provides the impulse response analysis. Figure 3.10 provides the generalized impulse response functions of y_t and k_t to a positive unit shock in KNIW.[115]

As is seen from the upper panel of Figure 3.10, y_t is initially negatively affected from an increase in KNIW. However, y_t is eventually positively affected from KNIW. That is, in the end a rise in the level of knowledge has favorable effects on output per worker. This result clearly shows the importance of the absorptive capacity. It takes time for the economy to establish the necessary infrastructure so as to absorb the new knowledge (or technology). This is consistent with the theoretical arguments that we have mentioned before (see Chapter 2): improvements in TFP (here, via knowledge indicators) is not "manna from heaven" but requires deliberate policy actions and is available at a cost.

Lastly, as can be seen from the lower panel of Figure 3.10, the dynamic effects of a rise in KNIW on k_t is not favorable. This result is also in line with the theory since

[115] We preferred generalized impulse responses rather than the ones based on Cholesky (orthogonalized) innovations because generalized impulse responses are not sensitive to the ranking of the variables within the model (Peseran and Shin, 1998).

higher level of knowledge (or a rise in total factor productivity) requires less capital per labor to produce same output.

Unlike much of the literature, which generally considers a single dimension of knowledge, such as human capital, we consider several dimensions of knowledge together. Thus, the key contribution of this study is that it gives us the opportunity to analyze the effect of knowledge diffusion channels together on the economic growth performance, which would otherwise be impossible due to the high collinearity between the variables. Secondly, to our best of knowledge, it analyzes the impact of various knowledge diffusion channels together for the first time in Turkey. Last, but not least, it has clearly shown that absorptive capacity is crucial to fully utilize the knowledge stock available in the economy and it takes time to see the returns of knowledge. Taken together, designing policies and programs that entail knowledge factors should envisage creation of an economic environment that is conducive to enhance the level of knowledge and hence long run economic growth in Turkey.

In order to shed more light on these results, in the following chapter we investigate the economic impact of knowledge at micro level to see the spillover effect it has on the productivity of manufacturing firms in Turkey using firm level panel data from 2003-2010.

CHAPTER 4

THE IMPACT OF KNOWLEDGE ON THE PRODUCTIVITY LEVEL OF FIRMS: A MICROECONOMIC ANALYSIS OF THE TURKISH MANUFACTURING SECTOR

A macro level analysis enables us to investigate the impact of knowledge on productivity by providing an insight on how knowledge indicators contribute to the economic growth of the overall economy. On the other hand, a micro (or firm) level analysis provides a "great deal of variability that occurs at lower levels, and that macro statistics often mask" (ONS, 2014: 142). Hence, micro data gives us the opportunity to analyze the relationships between determinants of growth (productivity) and knowledge indicators more closely.

Productivity is vital for the existence of firms. In other words firms with higher productivity have higher revenue growth and thus, lower probability of future exit. So, the level of productivity determines the success and hence the mere existence (survival) of firms. Therefore, majority of the firm level studies have focused on factors that contribute to the growth of productivity.[116] These factors are either firm specific (for example, size, human capital, R&D investment etc.) or external (for example, industry specific characteristics such as labor mobility, degree of concentration and institutional background) or both. For example, Griliches (1992, 1994) points to human capital, economies of scale and industry specific factors as the main determinants of firm level productivity.

[116] See, for example, Romer (1990), Grossman and Helpman (1991) and Cohen and Klepper (1991 and 1992).

In terms of catch-up, we have arguments similar to the ones that we have analyzed in the cross country analysis (see Chapter 2/Essay 1). On the one hand the argument is that growth rates of firms will eventually converge as new knowledge will be diffused to the follower firms. For example, Findlay (1978) argues that the higher the technological distance of follower firms from leader firms the faster the improvement will be in their productivity because there is so much to catch-up.[117] On the other hand, researchers such as Cohen and Levinthal (1990) argue that firms that are more similar to the leader, both in terms of technological knowledge and skills, will engage in similar R&D activities and will reach the productivity level of the leader much faster than the other (backward) followers.

There are only few studies that have investigated the relationship between the knowledge indicators and the economic growth performance of the firms in the manufacturing sector in Turkey. One of the most recent and thorough studies on the Turkish manufacturing sector is by Ülkü and Pamukçu (2015), who have investigated the impact of R&D and knowledge diffusion channels on the productivity of the Turkish manufacturing firms during the 2003-2007 period, using the Industry and Service Statistics database of the Turkish Statistical Institute (TurkStat). The results of this study indicate that an increase in R&D intensity leads to an increase in the productivity levels of firms that have technological capability above the threshold level. That is, the level of technological capability of firms determines both their ability to use the available R&D knowledge and their ability to undertake new R&D activities. Thus, we attempt to take Ülkü and Pamukçu's (2015) study one step further by utilizing a more comprehensive dataset, established by using three different data sets of TurkStat, i.e. the Industry and Service Statistics database, the Foreign Trade database and the R&D database for the 2003-2010 period. This is an important departure from Ülkü and Pamukçu (2015), that is, the R&D data that we will use in our analysis is compiled according to the Frascati

[117] As the follower firms Findlay (1978) considers domestic firms and he considers foreign firms as the leader firms, in our study we will use a different distinction.

Manual.[118] Our second departure will be the time period of our dataset which covers a longer time period -from 2003 to 2010- we believe that this will give us better insight on the R&D performance of firms in the Turkish manufacturing sector. This is important since as underlined by Mairesse and Kremp (1993) our understanding of productivity improves with the quality, relevance and scope of our data. Therefore, we hope that our new dataset will provide a better insight on the relationship between various factors of knowledge and the productivity of firms in the Turkish manufacturing sector.

The remainder of the chapter is organized as follows: The following section introduces an overview of the manufacturing sector of Turkey. Section 4.2 provides a literature review on theoretical and empirical studies followed by Section 4.3 which introduces our model and the empirical results. Finally, Section 4.4 provides the concluding remarks.

4.1. The Turkish Manufacturing Industry

The manufacturing sector has been one of the most important drivers of the Turkish economy. As can be seen from Figure 4.1 the share of manufacturing sector in GDP has been generally above 20% with the exception of crisis periods. In 2014, the manufacturing sector accounted for 24.2% of total GDP. The subsectors of the manufacturing sector have experienced substantial transformation[119] between 1996 and 2008. Especially due to competitive pressure coming from India and China, the share of garments, textile products and food decreased while the share of automotives, machinery, white goods, electronics, petroleum products and rubber-plastic products in the total manufacturing industry increased considerably.

[118] The R&D data Ülkü and Pamukçu (2015) have used is from the Industry and Service Statistics database.

[119] The manufacturing sector has been transformed from low technology -driven sectors to relatively higher technology- driven sectors.

The manufacturing sector has also had the largest share in the foreign trade of Turkey. As can be seen from Figure 4.2 even though the share of manufacturing in total trade has decreased during the 1998-2014 period, its share is still well above 80%. Thus, this sector continues to be the main engine of the Turkish economy. The distribution of the exports according to manufacturing sub sectors, provided in Appendix 4A, gives us a clear indication of the substantial transformation in the manufacturing sector during the last 30 years. However, there is also the other side of the coin. One of the most important problems in this sector is the high dependence on imported inputs, so rather than using domestic inputs imported inputs are used, especially by big manufacturing companies.

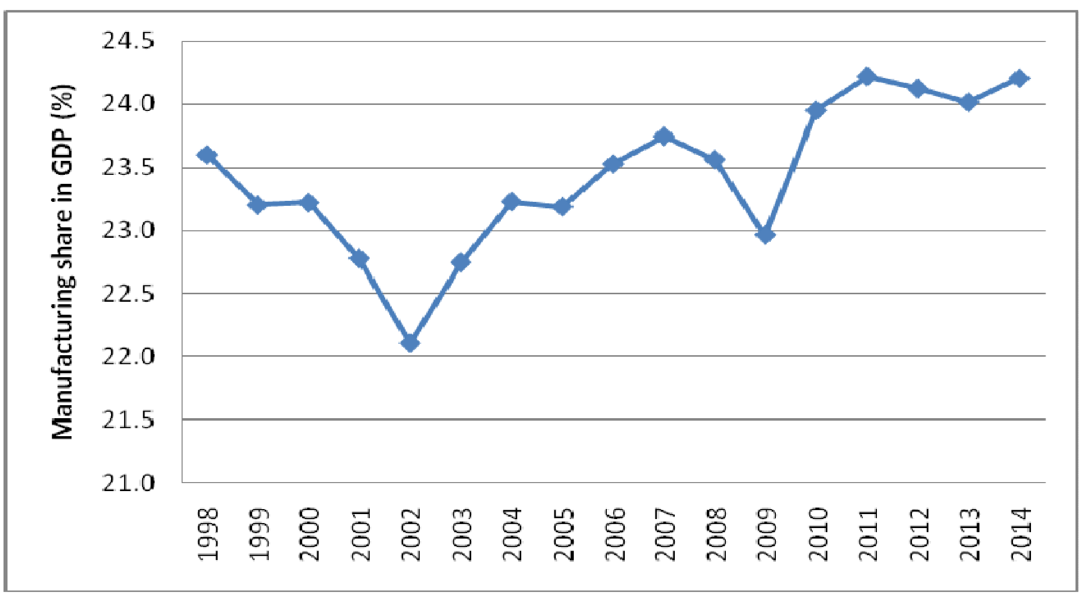

Figure 4.1 Share of Manufacturing Sector in GDP (%)[120]

[120] Prepared by the author using the information in www.tüik.gov.tr.

As can be seen from Table 4.1 the textile and leather (33%), metal products (11%), food (10%) and machinery (9%) are the largest sub-sectors in the manufacturing sector measured by the employees. This slightly changes when we look at the distribution of the number of employees in terms of foreign ownership.[121] In terms of foreign ownership the largest share is in textile and leather (15%), chemicals (13%), metal (11%), food (11.7%) and transport (11.6%) (see Table 4.1).

The total number of firms in the manufacturing sector has significantly increased from 2003 to 2008 from approximately 13.000 to 19.000, and in 2009 -mainly due to the global financial crisis- this number has decreased approximately to 16.000 (see Table 4.2). As can be seen from Table 4.2 the main impact of the 2008 global crisis has been on domestic firms which have decreased from approximately 18.000 in 2008 to 15.000 in 2009. The decrease in the number of foreign firms has been less drastic compared to the domestic firms (see Table 4.2).

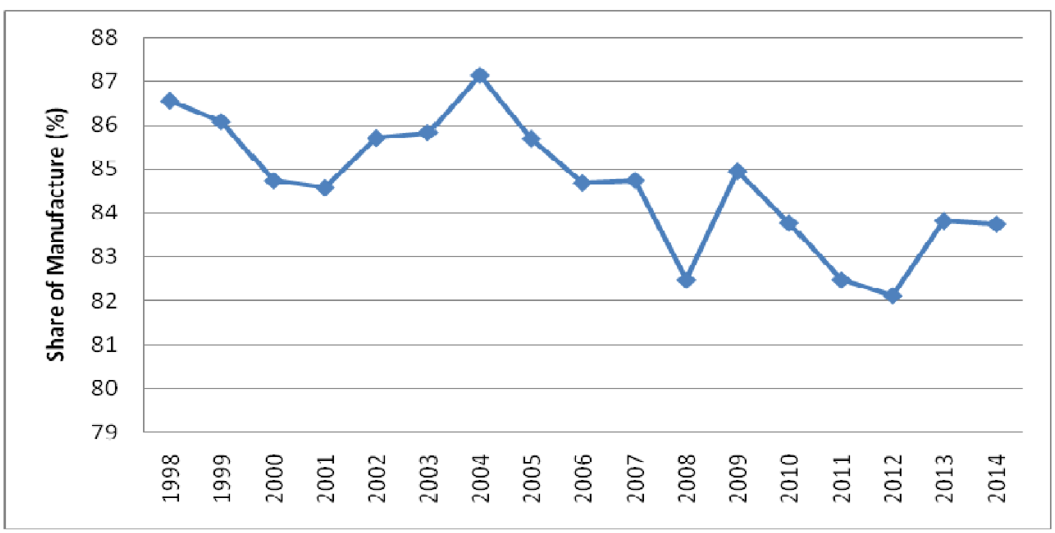

Figure 4.2 Share of Manufacturing Sector in Foreign Trade (%)[122]

[121] In our sample firms that have more than 10% foreign share are considered as foreign firms.

[122] Prepared by the author using the information in www.tüik.gov.tr.

Figure 4.3 provides the share of firms in the sub sectors in the Turkish manufacturing sector.[123] As can be seen with 35.1% the textile and leather sector is the largest sub sector in the manufacturing sector followed by metal products (11.6%), food (10.7%), machinery (8.9%), minerals (7.5%), transport (6.3%), plastic (6%), paper and publishing (5.9%), electrical (4.5%), chemicals (3.3%), coke and petroleum (0.2%) and recycling (0.1%).

Table 4.1. Percentage Share of Employees in Sectors Firms over the period 2003-2010 (Foreign, Domestic and Total)

Sectors	Domestic	Foreign	Total
Food	9.8	11.7	9.8
Textile_leather	34.0	14.6	33.3
Paper_publishing	5.6	4.9	5.5
Coke_petroleum	0.1	0.4	0.2
Chemicals	2.7	12.8	3.1
Plastic	5.7	8.0	5.8
Mineral	6.8	5.9	6.8
Metal	10.9	9.5	10.8
Machinery	8.7	7.7	8.7
Electronics	4.2	7.7	4.3
Transport	5.6	11.6	5.8
Furniture	5.7	4.0	5.6
Recycling	0.1	0.1	0.1

Source: Prepared by the author using the Industry and Service Statistics database.

Table 4.4 also provides information with regards to the distribution of firms according to the subsectors in 2010. As has been mentioned previously majority of the firms in manufacturing sector are engaged in textile and leather sector (4611) followed by metal (1815), food (1804), machinery (1371), minerals (1211), plastic

[123] The sub sectors of the manufacturing sector are formed using Nace 1.1 provided in Table 4A.1 of the Appendix section.

(980), paper and publishing (911), transport (876), electronic/electrical machines and devices (719), chemicals and products (488), recycling (27) and coke and petroleum (26).

In terms of foreign ownership, the share of foreign firms active in the Turkish manufacturing sector is approximately 11% of the firms engaged in the manufacturing sector (see Table 4.3). As can be seen from Figure 4.4 and Table 4.4, the share of foreign firms is the highest in the chemicals and products (19%), transportation vehicles (9%), coke and petroleum (7.7%) and electronic (7%) sub-sectors.

The total number of R&D performing firms in the manufacturing sector has increased from 1,426 in 2003 to 1,837 in 2006 then remained at a steady level until 2008 and decreased in 2009 and stayed approximately at the same level in 2010 (see Table 4.3).

When we analyze R&D conducting firms at sub-sector level, in 2010, coke-petroleum, chemicals, electrical and machinery sub-sector are the leading sectors in terms of their share within the firms actively engaged in R&D (see Table 4.4).

Table 4.2 Number of Firms in the Manufacturing Sector from 2003 to 2010

Year	Domestic	Foreign	Total
2003	12498	530	13028
2004	14610	606	15216
2005	18069	654	18723
2006	18623	804	19427
2007	18264	795	19059
2008	18276	759	19035
2009	15291	691	15982
2010	15100	682	15782

Source: Prepared by the author using the Industry and Service Statistics database.

Table 4.3 Number of R&D Performers in the Manufacturing Sector from 2003 to 2010

Year	Domestic	Foreign	Total
2003	1267	159	1426
2004	1420	178	1598
2005	1612	173	1785
2006	1631	206	1837
2007	1639	210	1849
2008	1651	199	1850
2009	1597	184	1781
2010	1587	180	1767

Source: Calculated by the author using the R&D database of TurkStat.

As can be seen from Table 4.5, 9.2% of the firms engaged in R&D are foreign firms. In 2010, the share of R&D conducting foreign firms was highest in the chemicals (22%), transport (20%) and food (17%) sub-sectors (see the last column of Table 4.4). In terms of domestic R&D firms, machinery, electronic, metals, textile and leather are the main sub-sectors that domestic conducting firms are engaged in R&D activities.

Table 4.5 indicates that during the 2003-2010 period on average 37.9% of the R&D firms conducted in house R&D. Percentage of foreign firms that conducted in house R&D annually was much higher than the domestic firms during the same period (96% and 67% respectively). Moreover, during the same period, foreign firms seem to be much better at taking advantage of knowledge diffusion channels –i.e. licensed technology stock per labor- than domestic firms. The percentage share of foreign firms that licensed technology during the same period was 78.4% whereas the share of the domestic firms that licensed technology was 56.2%.

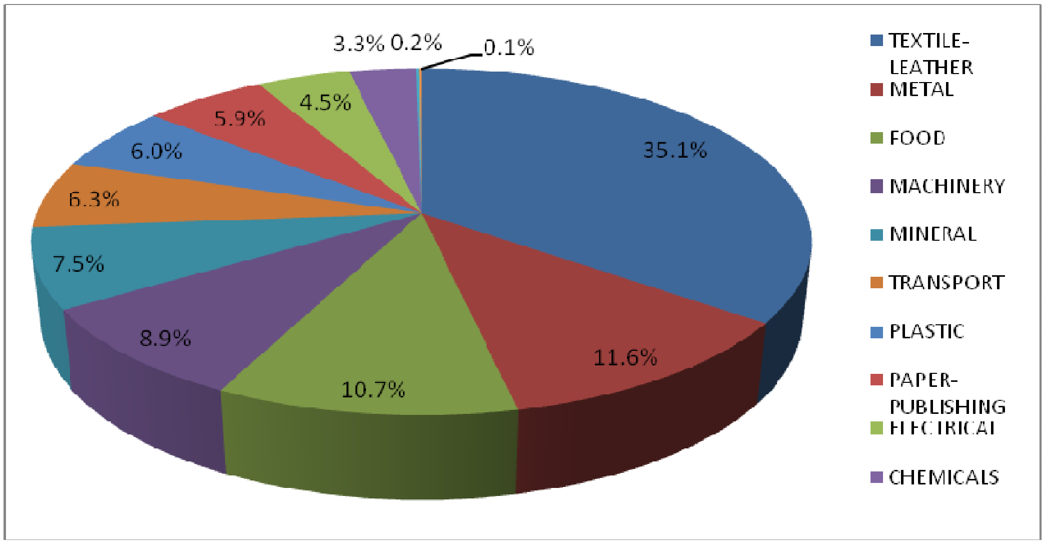

Figure 4.3 Share of Firms in the Sub Sectors of Manufacturing Sector in 2010 (%)[124]

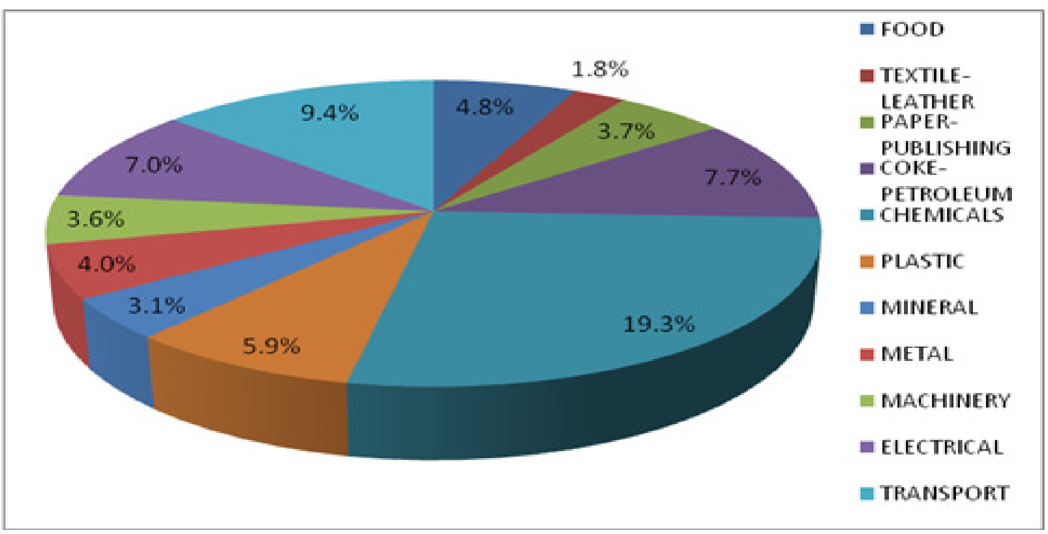

Figure 4.4 Share of Foreign Firms in the Sub Sectors of Manufacturing Sector in 2010 (%)[125]

[124] Calculated by the author using the Industry and Service Statistics database.

[125] Calculated by the author using the Industry and Service Statistics database.

Table 4.4 Distribution of Firms and R&D Performer Firms in Sub-Sectors in 2010

Sub Sectors	All Firms						R&D Performer Firms					
	Domestic		Foreign		Total		Domestic		Foreign		Total	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Food	1717	11.37	87	12.76	1804	11.43	119	82.07	26	17.93	145	8.04
Textile-Leather	4530	30.00	81	11.88	4611	29.22	147	93.63	10	6.37	157	3.40
Paper-Publishing	877	5.81	34	4.99	911	5.77	33	94.29	2	5.71	35	3.84
Coke-Petroleum	24	0.16	2	0.29	26	0.16	8	88.89	1	11.11	9	34.62
Chemicals	394	2.61	94	13.78	488	3.09	126	77.78	36	22.22	162	33.20
Plastic	922	6.11	58	8.50	980	6.21	112	90.32	12	9.68	124	12.65
Minerals	1174	7.77	37	5.43	1211	7.67	96	90.57	10	9.43	106	8.75
Metals	1743	11.54	72	10.56	1815	11.50	182	94.30	11	5.70	193	10.63
Machinery	1321	8.75	50	7.33	1371	8.69	360	95.24	18	4.76	378	27.57
Electrical	669	4.43	50	7.33	719	4.56	197	92.49	16	7.51	213	29.62
Transport	794	5.26	82	12.02	876	5.55	125	79.62	32	20.38	157	17.92
Recycling	27	0.18	0	0.00	27	0.17	2	82.07	0	0.00	2	8.04
TOTAL	**15100**	**96**	**682**	**4**	**15782**	**100**	**1507**	**90**	**174**	**10**	**1681**	**100**

Source : Calculated by the author using the Industry and Service Statistics database and the R&D database of TurkStat.

Table 4.5 Percentage share and mean values of some variables across various groups of firms (2003-2010 period)

	R&D firms	Non R&D	Domestic R&D	Foreign R&D	Domestic non-R&D	Foreign non-R&D
Number of observations	18903	150941	17061	1811	142575	4522
Number of firms	2438	16667	2207	225	15890	529
Foreign firms (%)	9.2	3.2	0.0	100	0.0	100
Firms conducting R&D (%)	100	0.0	45.3	54.7	0.0	0.0
Firms conducting in-house R&D (%)	37.9	0.0	36.3	52.7	0.0	0.0
Firms engaging in trade (%)	92.3	68.3	91.7	97.5	67.3	93.5
Firms licensing technology (%)	58.4	43.5	56.2	78.4	41.8	63.5
In house R&D/total R&D (%)	68	0.0	65.7	96	0.0	0.0
In house R&D/Labor (TL)	2492.6	0.0	2288.2	4317.2	0.0	0.0
In house R&D/revenue (%)	0.7	0.0	0.7	0.9	0.0	0.0
Technological capability (%)	23.2	0.1	21.6	38.0	0.1	0.2
Licensed technology/labor (TL)	1202	713	1221	1908.8	662	2296
Foreign ownership share (%)	9.2	3.2	0.0	29.8	0.0	70.2
Import/revenue (%)	46	23	43	75	23	51
Export/revenue (%)	36	24	38	18	25	25
Value added/labor (1000 TL)	62	32	57	106	31	88
Revenue/labor (1000 TL)	224	131	206	374	125	329
Labour	271	74	230	648	41	167
Depreciation allowance/labor (TL)	6902	3198	6439	1087	2995	9782
Herfindahl index (%)	4.5	3.4	4.4	5.4	3.3	4.6

Source : Calculated by the author using the Industry and Service Statistics database, the Foreign Trade database and the R&D database of TurkStat.

When we compare R&D firms (both domestic and foreign) to non-R&D firms we see that firms that have been engaged in R&D have performed better in terms of revenue per labor, technological capabilities and international trade (export plus imports) during the 2003-2010 period.

In terms of foreign trade performance, R&D conducting domestic and foreign firms have been involved in international trade more than non-R&D conducting firms during the 2003-2010 period. Moreover, in terms of utilizing the knowledge diffusion channels R&D firms have performed much better than the non R&D firms: the share of R&D firms that licensed technology was 58% while it was 44% for non-R&D firms. Similarly the R&D firms performed better in terms of technological capabilities compared to the non-R&D firms. As can be seen from Table 4.5 this is more apparent in the case of foreign firms.

In order to enhance R&D activities, Turkey prepared the "Vision 2023 Technology Foresight Program" with an aim to build a Science and Technology vision for Turkey, determine strategic technologies and priority areas of R&D, formulate S&T policies of Turkey, increase the spectrum of stakeholders involved in the process and create public awareness on the importance of S&T for socio-economic development (TUBİTAK, 2004). Out of the nine sectors covered in the program[126] five of them are manufacturing subsectors. With respect to the manufacturing subsectors it contains very ambitious targets for 2023. For example, it foresees Turkey to become the most preferred machine manufacturer in the world, i.e. the target is to secure 2.63% share of the global machinery market by 2023.

[126] These nine sectors are information and communication, energy and natural resources, health and pharmaceuticals, defense, aeronautics and space industries, agriculture and food, manufacturing and materials, transportation and tourism, chemicals and textiles and construction and infrastructure sectors.

4.2. Literature Review

In the literature, the analysis of the impact of knowledge on firm productivity generally focuses on the relationship between R&D activities of firms and their productivity level. The widely acclaimed studies by Aghion and Howitt (1992, 2008), Grossman and Helpman (1991) and Romer (1990), provide evidence on the strong relationship between knowledge variables and productivity. These studies view knowledge as an important input in the process of endogenous growth. Thus, following Aghion and Howitt (1992), Grossman and Helpman (1991), Cohen and Klepper (1991 and 1992), and Romer (1990) majority of the studies on knowledge and the productivity of firms consider R&D as the main source of knowledge.

Basically, the argument in this strand of the literature is that profit maximizing firms would invest in R&D activities to attain higher productivity (or growth) via new innovations or new products in the market. That is, R&D and thus innovation are seen as the engines of firm productivity. For example, Aghion and Howitt (1992), Lööf and Heshmati (2002), Hall and Mairesse (1995), Mairesse and Mohen (2005) and many others predict that long run growth rate of firms should be positively correlated with R&D productivity. Moreover, Cohen and Levinthal (1989) point R&D as the key indicator that shapes the absorptive capacity of the firm, via increasing its ability to "identify, assimilate, and exploit knowledge from the environment" (Cohen and Levinthal, 1989:569).

Thus, unsurprisingly, studies that have followed these seminal studies have focused on factors that enhance the R&D capabilities of firms. Firm size, FDI, technological opportunities in the industry, such as flow of patents, R&D spillovers, technological licensing have been analyzed and majority of studies have found that these factors had, directly or indirectly, a positive impact on the R&D levels, volume and activities of firms.[127]

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[127] See Klette and Griliches (1998) for more detail.

However, some studies have questioned this dominance of R&D in the literature in analyzing the productivity levels of firms. For example Crépon et al. (1998) and Blundell et al. (1993) argue that when R&D is considered by itself, there is the danger of loosing the impact of other activities (such as purchase of new machinery) in the analysis. Moreover, Crépon et al. (1998) find that different factors affected the outcomes of different types of innovation. That is, while R&D had a positive impact on firms' ability to introduce new products, firm's investment in fixed capital determined its ability to introduce process innovations.

Furthermore, compared to the macro strand, in the micro strand of the endogenous growth literature the impact of human capital as a knowledge variable is generally considered indirectly, i.e. it is considered as a precondition for R&D performance. There are only few studies that consider human capital along with R&D in analyzing the productivity performances of firms. For example, Ballot et al. (2002) in their study on the productivity of French and Swedish firms have included human capital as well as R&D in their model. They have found that human capital contributes positively to the productivities of both French and Swedish firms.[128]

Considering foreign trade, usually firms in industries open to trade are considered to have an information advantage[129] over other firms that produce and sell mainly for the domestic market. Moreover, knowledge spillovers[130] from international markets provide firms with the opportunity to improve their products and become

[128] Ballot et al. (2002) have also included an interaction between human capital and R&D into their model.

[129] For example, firms that are engaged in international interactions have the chance to receive know-how via imported goods or feedbacks from foreign markets on the exported products that could lead to further improvement of products or in some cases the feedback can result in a process innovation.

[130] Such as foreign know-how that is transmitted via the imported goods whether they are intermediate inputs or final consumption goods.

more competitive against both domestic and foreign rivals (Forbes and Wield, 2000).

As can be noticed these are the factors that shape the technological capabilities of firms which determines firms' proximity to the leading firm(s) and thus their capability to catch-up with the leading firms. That is, only firms that are more similar to the leader firms in terms of the level of knowledge would engage in similar activities to increase their productivity. Thus, we can say that the degree of heterogeneity among firms determine their catch-up efforts. For example, Lööf and Heshmati (2002) have found that knowledge capital[131] as the main factor determining the heterogeneity among the firms. Thus, the catch-up indicators we will utilize in our essay will also give us an idea about the extent of heterogeneity of firms in the Turkish manufacturing sector.

To our knowledge there are only few studies on the impact of knowledge on the Turkish economy and majority of these studies have investigated the relationship between R&D and growth on the Turkish manufacturing sector.

As indicated previously the most recent study is by Ülkü and Pamukçu (2015) which has investigated the impact of R&D and knowledge diffusion on the productivity levels of the firms in the Turkish manufacturing sector during the 2003-2007 period. They have found that factors such as foreign ownership, technology licensing, R&D intensity and industry level R&D spillovers increased productivity of the firm depending on its level of technological capability.

One other recent study is Kalaycı (2012) which, using firm-level data from TurkStat analyzed the impact of R&D on productivity of firms in the Turkish manufacturing sector. She investigated whether conducting R&D helps the lagging

[131] Lööf and Heshmati (2002) define knowledge capital as "innovation output measured as the percentage of innovation sales to total sales" (Lööf and Heshmati, 2002:63) which is different from the definition of knowledge employed throughout this thesis.

firms to attain sector leaders' productivity level. In contrast to Ülkü and Pamukçu (2015) she found that foreign ownership had no statistically significant effect on R&D intensity; and while foreign knowledge spillovers exerted a negative effect on R&D in the short-run, their effect became positive in the long-run. The R&D subsidies affected firms' productivity positively while the firm size affected it negatively. Moreover, she found that the effect of R&D and skill on productivity was positive and significant, while the effect of R&D on technical efficiency was negative. The knowledge spillovers on the other hand exerted a positive effect on the technical efficiency of the firms.

Lenger and Taymaz (2006), in their seminal study on the Turkish manufacturing sector, found that R&D intensity promoted innovation which, in turn, increased output and foreign firms transferred technology from abroad more than their domestic counterparts. Similarly, Pamukçu and Erdil (2011) have also found that subsidiaries of multinational companies in Turkey collaborated on R&D projects with other affiliates of the parent company located abroad and transferred new technology from their R&D centre. However, just like Kalaycı (2012), Lenger and Taymaz (2006), Üçdoğruk (2009) and Taymaz and Üçdoğruk (2009) found that there were no R&D spillovers from foreign firms to domestic firms and foreign ownership had no significant effect on R&D intensity.

4.3. The Model

In this section we will follow Ülkü and Pamukçu (2015) and extend their analysis on the impact of R&D and knowledge diffusion on the productivity of manufacturing firms in Turkey by using a more comprehensive dataset covering the 2003-2010 period. Thus in the remainder of this section first we will introduce Ülkü and Pamukçu's (2015) model and estimate the model with a new dataset for the period 2003-2010.

Ülkü and Pamukçu (2015) utilized a standard Cobb-Douglas production function where aggregate output is modeled as a function of an endogenous technological innovation, capital stock and labor as follows:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\alpha - 1} \tag{4.1}$$

where Y_{it} is output of firm i at time t, A is technology level of firm i at time t, K is physical capital of firm i at time t and L is labour input of firm i at time t.

Equation (4.1) implies that firms' growth rate of output is related to the growth rates of technology level stock (A_t) and capital stock (K_t). Technology level is modeled as follows:

$$A_{it} = f(r_{it}, tr_{it}, for_{it}, rs_{it}, rs_{for,it}, tl_{it}) \tag{4.2}$$

where r_{it} is in-house R&D stock per labour for firm i at time t, tr_{it} is trade in goods and services for firm i at time t, for_{it} is share of foreign ownership for i at time t, rs_{it} is R&D spillovers from other firms from the same four digit industry for firm i at time t, $rs_{for,it}$ is R&D spillovers from foreign firms from the same four digit industry for firm i at time t and tl_{it} is technology licensing for firm i at time t.

Then Equation (4.1) is divided by labor and after taking natural log (and incorporating Equation (4.2)) the following equation is obtained:

$$y_{it} = \alpha_1 k_{it} + \alpha_2 r_{it} + \alpha_3 tr_{it} + \alpha_4 for_{it} + \alpha_5 rs_{it} + \alpha_6 rs_{for,it} + \alpha_7 tl_{it} \qquad (4.3)$$

where y_{it} is labour productivity firm i at time t, k_{it} is per labour physical capital stock of firm i at time t and rest of the variables are as defined earlier.

Cohen and Levinthal (1990) and Yaşar (2013) along with many other researchers argue that the absorptive capacity and technological capability are important determinants of higher rates of firm productivity, since these capabilities are the determinants of better utilization of firms' own R&D and diffusion channels. Departure of Ülkü and Pamukçu (2015) is that they have incorporated technological capability (tc) variable into their model to investigate whether this argument holds for the firms in the Turkish manufacturing sector.

Then Ülkü and Pamukçu (2015) have completed the model by adding the indicators of technological capability, Herfindahl index and interaction terms between per labour in-house R&D stock and technology catch-up, between share of revenue and technology catch-up, between per labour licensed technology stock and technology catch-up, between per labour R&D spillovers and technology catch-up and between per labour R&D spillovers from foreign firms and technology catch-up and industry and year dummies as follows:

$$\begin{aligned} y_{it} &= \alpha_0 + \alpha_1 k_{it} + \alpha_2 r_{it} + \alpha_3 tr_{it} + \alpha_4 for_{it} + \alpha_5 rs_{it} + \alpha_6 rs_{for,it} + \alpha_7 tl_{it} + \alpha_8 tc_{it} + \alpha_9 herf_{it} \\ &+ \alpha_{10}(r\_tc)_{it} + \alpha_{11}(tr\_tc)_{it} + \alpha_{12}(tl\_tc)_{it} + \alpha_{13}(rs\_tc)_{it} \\ &+ \alpha_{14}(rs_{fdi}\_tc)_{it} + \beta_1 ind + \beta_2 yr \end{aligned} \qquad (4.4)$$

where $herf_{it}$ is the herfindahl index, tc_{it} is the technological capability firm i at time t, r_tc_{it} is an interaction terms between per labour in-house R&D stock and technology catch-up, tr_tc_{it} is an interaction term between trade share of revenue and technology catch-up, tl_tc_{it}

is an interaction term between per labour licensed technology stock and technology catch-up, rs_tc_{it} is an interaction term between per labour R&D spillovers and technology catch-up, $rs_{for}\_tc_{it}$ is an interaction term between per labour R&D spillovers from foreign firms and technology catch-up, ind is industry and yr is year dummies that are included to take into account heterogeneity across industries and common shocks to firms and the other variables are as defined before.

By following Yaşar and Morrison (2012) and Kokko (1994), Ülkü and Pamukçu (2015) have introduced all the diffusion channels, in-house R&D, Herfindahl index into the production function through an innovation function so that these variables serve as shift variables.

4.3.1. Definitions and Data Sources

In this sub-section we provide the definitions and the sources of data that we will use in our analysis.

Labour productivity (y) is the total value added per labor and is calculated as the log of deflated manufacturing industry revenue per labor as follows:

$y = \log[((M_{rev}/sec\_def)x100)/E]$

where M_{rev} is the revenue obtained from the sales of the manufacturing sector products, sec_def is the sector deflator (2003=100) at four digit industry level and E is the number of employees.

Physical capital (k) is the depreciation allowance (proxy of physical capital stock) per labor and is calculated as the log of depreciation divided by labor as follows:

$k = \log [((dep/sec\_def)x100)/E]$

where dep is depreciation and the other variables are as defined earlier.

<u>In-house R&D stock per labour (r)</u> is the total in-house R&D expenditure per labor and is calculated as the log of stock of total in house R&D expenditure of firms divided by labor.

Following Griliches (1980), in order to evaluate firms' R&D efforts, Ülkü and Pamukçu (2015) rather than using flow variables have preferred to use stock variables since the latter is a better proxy because the impact of R&D efforts persists over several years. We will follow them and calculate all the stock values[132] by using the perpetual inventory method as follows:

i. The initial level of stock is calculated using the following standard formula:

$$Rs_{t-1} = R_t \ / \ (r\delta)$$

where Rs_{t-1} is the initial R&D stock, R_t is the R&D expenditure at time t, r is the 4 digit sector level average growth rate of R&D flow and δ is the depreciation rate (assumed to be 15%).

ii. Then the R&D stock for the following years is calculated using perpetual inventory method as follows:

$$Rs_t = R_t + (1\text{-}\delta)\ Rs_{t-1}$$

where Rs_t is the R&D stock at time t and the other variables are as defined before.

We do expect positive impact of in-house R&D stock on the firms' productivity growth.

[132] That is, the stock variables of the R&D and technology diffusion.

Herfindahl index (herf) is the measure of market concentration and helps us to measure the competition level in the market.[133] It is defined as the sum of the squared market shares of firms in the sector at the four digit industry level. Market share is the total product stock ready for sale share of a firm in its four-digit industry level.

A low level of market concentration indicates high competition, i.e. there are many firms in the market.

Trade in goods and services (tr) is calculated as the share of revenue from foreign trade in total revenue and foreign trade is the sum of exports and imports of goods and services. If a firm engages in foreign trade as an exporter than that firm would have higher incentive to improve its ability to compete. Moreover, imports could also contribute to the competitiveness of the firm via the imported know-how.

Share of foreign ownership (for) is the ratio of foreign capital to total capital. Foreign ownership could either have a negative effect or a positive effect[134] or in some cases even no effect on productivity. In case the local affiliate is at production stage under the name of the parent firm, we expect a negative relationship (Tandoğan, 2011), but if it has started R&D activities, the foreign owner may back it up and we could see a positive relationship.

R&D spillovers per labor (rs) is calculated as the stock of four digit industry level R&D expenditure of all firms (excluding firms' own R&D stock) divided by labor.

Licensed technology stock per labor (tl) is the licensed technology stock per labour. It is calculated as the stock of total intangible assets acquired by firms,

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[133] See Sun (2010) and Wiel (2010) for more detail.

[134] See, for example, Fu (2008), Lin and Yeh (2005), Karray and Kriaa (2009) and Kathuria (2010) for more detail.

including technology licenses, patents, software and other intangible assets, divided by the number of employees.

<u>R&D spillovers from foreign firms per labour (rs_{for})</u> is the stock of industry level R&D expenditure of firms with a foreign ownership of 10% and above at the four digit industry level (excluding firms' own R&D stock) divided by number of employees.

<u>Technological capabilities (tc)</u> is the in-house R&D stock of the firm divided by highest in-house R&D stock in the same four digit industry.

As indicated before, the model (Equation 4.4) also includes ***interaction terms*** to determine whether those firms closer to the leading firms in terms of technological capabilities can catch up the leaders faster than the firms that are lagging behind in terms of technological capabilities. These catch up (interaction) terms are;

- an interaction term between per labour in-house R&D stock and technological capabilities (r_tc);
- an interaction term between trade share of revenue and technological capabilities (tr_tc);
- an interaction term between per labour licensed technology stock and technology catch-up (tl_tc);
- an interaction term between per labour R&D spillovers and technological capabilities (rs_tc);
- and an interaction term between per labour R&D spillovers from foreign firms and technological capabilities (rs_{for_tc}).

Ülkü and Pamukçu (2015) have used the Industry and Service Statistics Database in their analysis. As noted before, we will depart from their study by establishing a new dataset as explained below.

Three surveys from Turkish Institute of Statistics (TurkStat) will be used in this study, namely; the R&D, Foreign Trade and Structural Business Surveys (SBS). The three surveys were matched at firm level. The most important aspect of this new data set is that we will use R&D data that has been compiled according to the Frascati Manual.[135]

As can be seen from Figure 4.7 the data for the three surveys were provided separately for each year in a different data base. Therefore before matching the three different surveys, first the survey of each year in the R&D survey data was combined (appended) by firm id from 2003 to 2010. The key for each firm provided by TurkStat to link all data files to one another was called 'ARGEYIIDISTIC'. The same key was provided in the SBS survey data as well. After combining (appending) the other two surveys from 2003 to 2010, first the combined SBS survey data was merged with the combined R&D survey data using 'ARGEYIIDISTIC' and year as the key identifiers. Table 4.6 provides yearly information on the number of firms that participated in each survey.

Later this "merged file" of the two surveys was further merged with the foreign trade survey using firm id and year as the key identifiers. The firms that did not have counterparts in all three surveys were dropped. Since the aim of the study is to analyze the manufacturing sector, only the data on firms that were active in this sector were kept, the other sectors were dropped. Moreover, firms that had less than 20 employees were dropped because TurkStat does not visit all of these firms and

[135] The Frascati Manual defines R&D as "creative work undertaken on a systematic basis in order to increase the stock of knowledge of man and society, and the use of this stock in order to devise new applications" (OECD, 1993:29).

instead interpolates some observations based on collected observations (due to financial and time constraints).

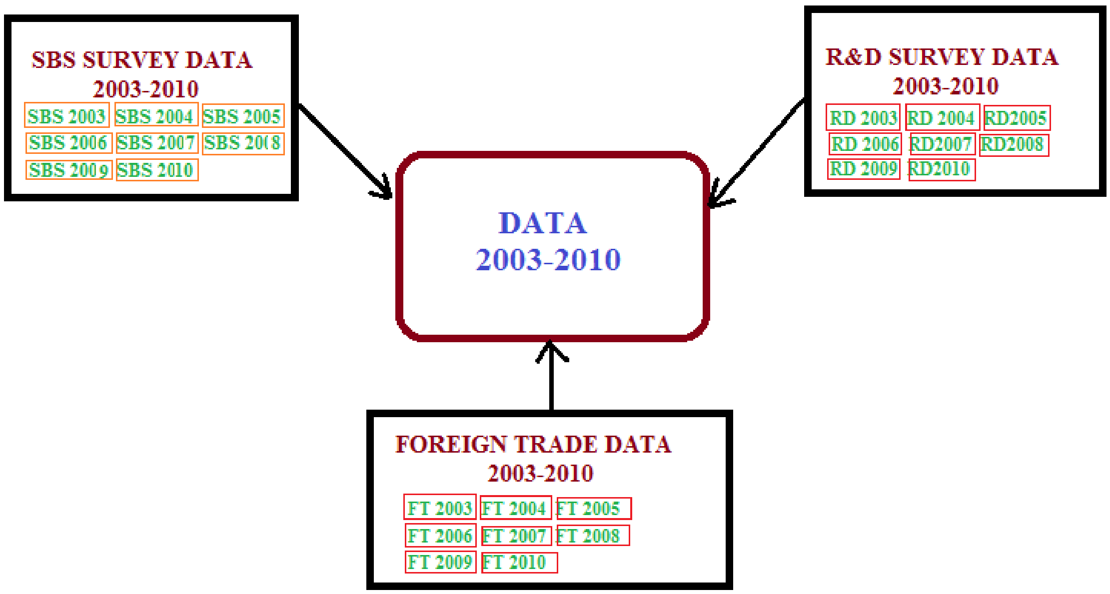

Figure 4.5 Data Structure

To see the differences between the subsectors of the manufacturing sector, sector dummy variables were generated following the NACE (Nomenclature générale des Activités économiques dans les Communautés Européennes" (Statistical classification of economic activities in the European Communities). TurkStat has used NACE revision 1.1 classification until 2009 and from 2009 onwards it has switched to NACE revision 2 classification. Therefore, in order to prevent any mistakes related to the NACE switch, by using a correspondence table of NACE 1.1 and NACE 2 classification we created a new variable and classifications for each year was in the form of NACE 1.1 classification.[136] Then, to determine the

le of Nace 1.1 and Nace 2 used in our study.

subsectors that the firms were in we took the mode of the four-digit industry codes listed for each firm and assigned the firm to the mode of subsectors that it was active in. The subsector dummies are important because the subsectors vary from one another in terms of knowledge bases; for example chemicals provide higher opportunities for R&D than textiles. Thus, by using the sector dummies we will take account of these technological opportunities between the subsectors. Time dummies were also included to capture technological advancement and macroeconomic factors affecting all firms.

Table 4.6 Total Number of Firms in Each TurkStat Survey

Year	SBS Survey	R&D Survey	Foreign Trade Survey
2003	77592	840	62945
2004	78463	869	69476
2005	63304	1540	74422
2006	85016	1598	78133
2007	83963	2031	87749
2008	82662	2379	85910
2009	99921	3101	83670
2010	106715	3610	87610

Source: Prepared by the author using the Industry and Service Statistics database, the Foreign Trade database and the R&D database of TurkStat

In our empirical analysis, the data for R&D variables is obtained from the R&D survey data, foreign trade data is obtained from the foreign trade survey data and the rest is obtained from the structural business survey data. The descriptive statistics of the variables used in the analysis and the correlation matrix of the variables are presented in Table 4.7 and 4.8 respectively.

Table 4.7 Descriptive statistics of the variables for the full sample (2003-2010)

VARIABLE	DEFINITION	N	MEAN	MIN	MAX	STD. DEV
Labor productivity (y)	Log of per labor value added of firm	16152	10.63	3.20	14.50	0.96
Physical Capital stock/labor (k)	Log of physical capital depreciation per labor	16152	7.35	0.00	12.70	2.89
In house R&D stock/labor (r)	Log of in house own R&D stock of a firm per labor	18903	1.88	0.00	13.40	3.56
Herfindahl index (herf)	Herfindahl concentration index or market product stock	18903	0.04	0.00	1.00	0.08
Trade/Revenue (tr)	Share of imports and exports in total revenue (%)	15766	17.11	0.00	147.95	27.94
Technological capability (tc)	In house R&D stock for a firm/in-house R&D stock of the sector leader in-house R&D stock per labour	18891	0.03	0.00	4.19	0.16
Foreign ownership share (%) (for)	Share of foreign capital (%)	18872	5.86	0.00	100.00	20.92
R&D spillovers/labor (rs)	Log of total (foreign and domestic firms) R&D stock spillovers constructed at the sector level technology licensing	16799	13.35	0.00	15.45	1.30
Licensed technology stock/labor (tl)	Log of total stock of intangible assets spillovers constructed at the sector level	16799	3.31	0.00	14.30	3.58
R&D spillovers from FDI/labor (rs_{for})	Log of foreign R&D spillovers constructed at the sector level	17991	12.64	0.00	18.03	3.04
TC*in-house R&D stock/labor (rs)	Interaction terms between per labour in-house R&D stock and technology catch-up	17979	0.27	0.00	39.88	1.61
TC*Trade/Revenue (tr_tc)	Interaction term between trade share of revenue and technology catch-up	15754	1.06	0.00	268.23	9.36
TC*Licensed technology stock/labor (tl_tc)	Interaction term between per labour licensed technology stock and technology catch-up	16787	0.21	0.00	36.32	1.41
TC*R&D spillovers/labor (rs_tc)	Interaction term between per labour R&D spillovers and technology catch-up	16787	0.40	0.00	53.51	2.20
TC*R&D spillovers from foreign firms/labor (rs_{for}_tc)	Interaction term between per labour R&D spillovers from foreign firms and technology catch-up	17979	0.25	0.00	40.16	1.40

Table 4.8 Correlation table for the full sample (2003-2010)

	y	y_{t-1}	k	r	herf4	tr	tc	rs	tl	rs_{for}	tr_tc	rs_tc	tl_tc	rs_{tor}_tc	r_tc
y	1														
y_{t-1}	0.6328*	1													
k	0.4066*	0.3861*	1												
r	0.1475*	0.1475*	0.1033*	1											
herf4	0.0368*	0.0404*	0.0320*	0.0321*	1										
tr	0.2356*	0.2469*	0.1856*	0.1980*	-0.0165*	1									
tc	0.0898*	0.0927*	0.0587*	0.3874*	0.0329*	0.1327*	1								
rs	0.1115*	0.1249*	0.0601*	0.1002*	-0.0632*	0.0591*	0.0022	1							
tl	0.2769*	0.2752*	0.2434*	0.1983*	0.0113*	0.2212*	0.1112*	0.0621*	1						
rs_{for}	-0.0471*	-0.0624*	-0.0367*	0.0091*	0.1216*	-0.0776*	-0.0550*	0.1989*	-0.0758*	1					
tr_tc	0.0623*	0.0659*	0.0385*	0.2543*	0.0032	0.1877*	0.7355*	0.0035	0.0701*	-0.0258*	1				
rs_tc	0.0900*	0.0965*	0.0587*	0.3934*	0.0276*	0.1379*	0.9917*	0.0144*	0.1130*	-0.0534*	0.7572*	1			
tl_tc	0.0793*	0.0861*	0.0516*	0.3284*	0.0286*	0.1202*	0.9403*	0.0150*	0.1192*	-0.0476*	0.7378*	0.9530*	1		
rs_{tor}_tc	0.0932*	0.0976*	0.0599*	0.3950*	0.0093*	0.1419*	0.8267*	0.0185*	0.1108*	-0.0185*	0.7229*	0.8362*	0.7780*	1	
r_tc	0.0867*	0.0910*	0.0562*	0.3756*	0.0294*	0.1293*	0.9867*	0.0108*	0.1097*	-0.0508*	0.7410*	0.9909*	0.9580*	0.8175*	1

Note: * indicates 5% significance level.

4.3.2. The Empirical Model

Equation (4.4) is re-stated for empirical purpose in stochastic form as follows:

$$
\begin{aligned}
y_{it} &= \alpha_0 + \alpha_1 k_{it} + \alpha_2 r_{it} + \alpha_3 tr_{it} + \alpha_4 for_{it} + \alpha_5 rs_{it} + \alpha_6 rs_{for,it} + \alpha_7 tl_{it} + \alpha_8 tc_{it} + \alpha_9 herf_{it} \\
&+ \alpha_{10}(r\_tc)_{it} + \alpha_{11}(tr\_tc)_{it} + \alpha_{12}(tl\_tc)_{it} + \alpha_{13}(rs\_tc)_{it} \\
&+ \alpha_{14}(rs_{fdi}\_tc)_{it} + \beta_1 ind + \beta_2 yr + \varepsilon_{it}
\end{aligned} \tag{4.5}
$$

where all the variables are as defined before and ε_{it} is the error term.

Ülkü and Pamukçu (2015) have first provided an carried out least squares (OLS) estimation, as they indicate this estimation takes into account first order autocorrelation (AR1), industry fixed effects, year effects and heteroskedasticity. Then, in order to control for the endogeneity problem, they have used two step system GMM method following Blundell and Bond (1998).

The generalized method of moments (GMM) method is widely used in dynamic panel data analysis. There are two popular GMM estimator used in the literature and they are the difference GMM estimator (widely referred to as Arellano–Bond estimation) and the system GMM estimators (Blundell and Bond, 1998). Both are general estimators designed for situations with few time periods and many individuals. The difference GMM estimation starts by transforming all regressors (i.e. differencing) and uses the generalized method of moments whereas the system GMM allows for more instruments and improves efficiency.[137] That is, it builds a system of two equations that contains the original equation and the transformed equation and is sometimes referred to as the two-step System GMM estimator.[138]

[137] As will be explained in more detail in the next section the maximum number of instruments used in our regression models is 298 for the full sample and 284 for the domestic sample.

[138] See Roodman (2009) for more detail.

An important advantage of the two-step System GMM estimator is that it is consistent even in the presence of unit root (Binder et al., 2003).

Ülkü and Pamukçu (2015) have used system GMM instead of difference GMM analysis since the latter has poor precision when the series are persistent and yields less efficient estimators when the number of time series observations is small and N is large (Blundell and Bond 1998). This is the exact situation with our data where our time dimension is eight years (2003-2010) and we have a large N (13960). This is also the first condition for System GMM results to hold, i.e. small T and large N. The second condition is that the instruments should be valid, which is determined according to the results of the Hansen Test.[139] In addition to the differences taken in the difference GMM in this case levels are also used, i.e. lagged differences instrument the levels. It is assumed that the past changes in the dependent variable are not correlated with the current periods' error in levels, including fixed effects. The other condition is that there should be no second order autocorrelation in first differences. That is, in line with Arellano-Bond test for AR(1) and AR(2), the null hypothesis states that there is no autocorrelation in first differences and as Roodman (2008) underlines there should not be second order autocorrelation in the series, i.e. we need to fail to reject the Arellano Bond test for AR(2) so as to avoid second degree autocorrelation in first differences.

4.3.3. The Estimation Results

We have estimated a benchmark model based on OLS estimation with time and industry dummies and lagged dependent variable (i.e. log labor productivity). The results of the benchmark model for the full sample and domestic sample are reported in Table 4.9 and Table 4.10, respectively. In both full sample and domestic sample benchmark models most of the variables are statistically significant and

[139] The null hypothesis is that the instruments are valid.

have the expected signs. However, these results can only give us preliminary information about the relations between the variables due to the possibility of endogeneity.

To deal with the endogeneity of firm-level variables, Ülkü and Pamukçu (2015) have employed two-step system GMM estimation technique. One important feature of this estimation technique is that it does not assume normality and it allows for heteroskedasticity in the data which is a common problem of dynamic panel models that can be controlled (Baltagi, 2008).

The two step system estimation approach assumes linearity and no second order autocorrelation, in other words the applied instruments in the model are exogenous. So we test for both the validity of instruments (Hansen Test) and for autocorrelation in the error terms. The system GMM estimator requires that there is first-order serial correlation and no second-order serial correlation in the residuals.[140]

Ülkü and Pamukçu (2015) in their regression models have used maximum 96 instruments for the full sample and 91 instruments in the domestic sample whereas in our regression models we have used maximum 298 and 284 instruments in our full sample and domestic sample, respectively.[141] In our analysis both the full sample and the domestic regressions use unbalanced panel data from 1695 manufacturing firms that were present in the dataset at least four times and more during 2003–2010 period, providing us with 10242 observations.[142] This has provided us with valid instruments and no second order autocorrelation (see Table

[140] The null hypotheses are that there is no first-order or second-order serial correlation however one needs to reject the null hypothesis of no first-order but not second-order serial correlation to get appropriate diagnostics (Arrelano and Bond, 1991).

[141] We have used lags 2 through 6 of the levels as instruments for the transformed data, i.e. laglimits (2 6).

[142] Including lagged dependent variables, industry and year dummies. In the dataset that we have used the number of firms that have been in the sample once was 170; twice 324; three times 642; four times 1436; five times 1730 and six times 5940 during the 2003-2010 period. Six times was the maximum number of years that firms have been present in the regression sample.

4.11 and Table 4.12) compared to other numerous alternative regressions that we have tried.

The results of our two step system GMM analysis for the full sample and the domestic sample are provided in Table 4.11 and Table 4.12, respectively. In the full sample capital stock, trade and licensed technology stock remain statistically significant with the expected signs (see Table 4.11). In the domestic sample, in addition to these variables in house R&D (only in model 3 and 6) and interaction terms between technological capability and trade are statistically significant with the expected sign (see Table 4.12). This result seems to suggest that there is relationship between trade and technological capability in the Turkish manufacturing sector.

Compared to Ülkü and Pamukçu (2015) the first difference between the estimation results of the full sample is that in their estimation foreign ownership share, licensed technology, and the interaction terms between technological capability and in-house R&D intensity and R&D spillovers from FDI are significant with the expected signs. Whereas in our results the lag values of the dependent variables, physical capital stock per labor, trade revenue and the licensed technology per labor are significant with the expected signs. In terms of the interaction terms, unlike Ülkü and Pamukçu (2015), the interaction terms between technological capability and in-house R&D intensity and R&D spillovers from FDI are insignificant.

On the other hand, in the case of the domestic sample contrary to Ülkü and Pamukçu (2015) in our analysis, once again the lagged values of the dependent variables, physical capital stock per labor, trade revenue and the interaction term between technological capability and trade are significant with the expected signs. This can be interpreted as a reflection of the importance of trade for the domestic firms in the Turkish manufacturing sector.

Table 4.9. Baseline Regression Analysis of Labor Productivity, y, Full Sample, 2003-2010

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6
Lag of labor productivity (y_{t-1})	0.4153***	0.4152***	0.4153***	0.4152***	0.4149***	0.4153***
	[0.0092]	[0.0092]	[0.0092]	[0.0092]	[0.0092]	[0.0092]
Lag of labor productivity (y_{t-2})	0.2468***	0.2468***	0.2468***	0.2469***	0.2465***	0.2468***
	[0.0087]	[0.0087]	[0.0087]	[0.0087]	[0.0087]	[0.0087]
Physical Capital stock/labor (k)	0.0449***	0.0449***	0.0449***	0.0449***	0.0449***	0.0449***
	[0.0025]	[0.0025]	[0.0025]	[0.0025]	[0.0025]	[0.0025]
In house R&D stock/labor (r)	0.0044**	0.0044**	0.0044**	0.0042**	0.0041**	0.0043**
	[0.0018]	[0.0018]	[0.0018]	[0.0018]	[0.0018]	[0.0018]
Herfindahl index (herf)	0.2308***	0.2352***	0.2321***	0.2455***	0.2482***	0.2308***
	[0.0842]	[0.0844]	[0.0844]	[0.0848]	[0.0850]	[0.0842]
Trade/Revenue (tr)	0.0012***	0.0012***	0.0011***	0.0011***	0.0011***	0.0012***
	[0.0002]	[0.0002]	[0.0002]	[0.0002]	[0.0002]	[0.0002]
Technological capability (tc)	0.0746*	-0.1874	0.0630	-0.5061	-0.0762	0.1020
	[0.0409]	[0.2829]	[0.0606]	[0.4037]	[0.1075]	[0.1077]
Foreign ownership share (for)	0.0011***	0.0011***	0.0010***	0.0010***	0.0010***	0.0011***
	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]
R&D spillovers/labor (rs)	-0.0144**	-0.0151**	-0.0145**	-0.0159**	-0.0140**	-0.0143**
	[0.0062]	[0.0063]	[0.0062]	[0.0063]	[0.0062]	[0.0063]
Licensed technology stock/labor (tl)	0.0082***	0.0082***	0.0082***	0.0081***	0.0082***	0.0083***
	[0.0017]	[0.0017]	[0.0017]	[0.0017]	[0.0017]	[0.0018]
R&D spillovers from FDI per labor (rs_{for})	0.0070***	0.0070***	0.0070***	0.0070***	0.0065***	0.0071***
	[0.0022]	[0.0022]	[0.0022]	[0.0022]	[0.0022]	[0.0022]
TC*Trade/Revenue (tr_tc)		0.0277				
		[0.0296]				
TC*R&D spillovers/labor (rs_tc)			0.0002			
			[0.0008]			
TC*Licensed technology stock/labor (tl_tc)				0.0457		
				[0.0316]		
TC*R&D spillovers from for ownership/labor (rs_{for}_tc)					0.0172	
					[0.0113]	
TC*in-house R&D stock/labor (r_tc)						-0.0037
						[0.0135]
Constant	3.4037***	3.4129***	3.4040***	3.4245***	3.4110***	3.4020***
	[0.1076]	[0.1080]	[0.1076]	[0.1085]	[0.1077]	[0.1078]
Observations	10242	10242	10242	10242	10242	10242
R-squared	0.545	0.545	0.545	0.545	0.545	0.545

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

Table 4.10. Baseline Regression Analysis of Labor Productivity, y, Domestic Sample, 2003-2010

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6
Lag of labor productivity (y_{t-1})	0.4085***	0.4084***	0.4086***	0.4083***	0.4080***	0.4085***
	[0.0097]	[0.0097]	[0.0097]	[0.0097]	[0.0097]	[0.0097]
Lag of labor productivity (y_{t-2})	0.2454***	0.2455***	0.2456***	0.2455***	0.2451***	0.2454***
	[0.0091]	[0.0091]	[0.0091]	[0.0091]	[0.0091]	[0.0091]
Physical Capital stock/labor (k)	0.0440***	0.0441***	0.0441***	0.0441***	0.0440***	0.0440***
	[0.0025]	[0.0025]	[0.0025]	[0.0025]	[0.0025]	[0.0025]
In house R&D stock/labor (r)	0.0043**	0.0044**	0.0045**	0.0043**	0.0040**	0.0043**
	[0.0019]	[0.0019]	[0.0019]	[0.0019]	[0.0019]	[0.0019]
Herfindahl index (herf)	0.2579***	0.2636***	0.2659***	0.2782***	0.2766***	0.2579***
	[0.0912]	[0.0914]	[0.0914]	[0.0923]	[0.0920]	[0.0912]
Trade/Revenue (tr)	0.0015***	0.0015***	0.0014***	0.0015***	0.0015***	0.0015***
	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]
Technological capability (tc)	0.0956	-0.1975	0.0293	-0.5495	-0.0487	0.1399
	[0.0582]	[0.3101]	[0.0780]	[0.4637]	[0.1116]	[0.1235]
R&D spillovers/labor (rs)	-0.0127*	-0.0134**	-0.0131**	-0.0139**	-0.0121*	-0.0125*
	[0.0065]	[0.0066]	[0.0065]	[0.0066]	[0.0065]	[0.0065]
Licensed technology stock/labor (tl)	0.0083***	0.0083***	0.0083***	0.0083***	0.0083***	0.0085***
	[0.0018]	[0.0018]	[0.0018]	[0.0018]	[0.0018]	[0.0018]
R&D spillovers from FDI per labor (rs_{for})	0.0066***	0.0066***	0.0066***	0.0066***	0.0061***	0.0066***
	[0.0023]	[0.0023]	[0.0023]	[0.0023]	[0.0023]	[0.0023]
TC*Trade/Revenue (tr_tc)		0.0309				
		[0.0321]				
TC*R&D spillovers/labor (rs_tc)			0.0015			
			[0.0012]			
TC*Licensed technology stock/labor (tl_tc)				0.0505		
				[0.0360]		
TC*R&D spillovers from for ownership/labor (rs_{for}_tc)					0.0185	
					[0.0122]	
TC*in-house R&D stock/labor (r_tc)						-0.0068
						[0.0167]
Constant	3.4692***	3.4785***	3.4746***	3.4878***	3.4761***	3.4665***
	[0.1126]	[0.1130]	[0.1127]	[0.1134]	[0.1127]	[0.1128]
Observations	9260	9260	9260	9260	9260	9260
R-squared	0.522	0.522	0.522	0.522	0.522	0.522

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

Table 4.11. Two Step GMM System Regression Analysis of Labor Productivity, y, Full Sample, 2003-2010

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
First Lag of labor productivity per labor (y_{t-1})	0.306***	0.312***	0.294***	0.316***	0.341***	0.326***
	[0.062]	[0.060]	[0.061]	[0.063]	[0.062]	[0.061]
Second Lag of labor productivity per labor (y_{t-2})	0.080***	0.080***	0.082***	0.083***	0.083***	0.078***
	[0.021]	[0.021]	[0.021]	[0.021]	[0.021]	[0.021]
Physical Capital stock per labor (k)	0.041***	0.043***	0.045***	0.044***	0.042***	0.040***
	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]
In house R&D stock per labor (r)	0.007	0.009	0.010	0.010	0.007	0.009
	[0.007]	[0.007]	[0.007]	[0.007]	[0.006]	[0.007]
Herfindahl index (herf)	0.117	0.225	0.039	0.112	0.009	0.254
	[0.656]	[0.648]	[0.649]	[0.633]	[0.650]	[0.661]
Trade/Revenue (tr)	0.004***	0.004***	0.003***	0.004***	0.003***	0.003***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Technological capability (tc)	0.072	-0.160	-0.072	-0.195	-0.045	0.019
	[0.065]	[0.328]	[0.109]	[0.632]	[0.134]	[0.167]
Foreign ownership share (for)	0.000	0.000	-0.000	-0.000	-0.000	0.000
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
R&D spillovers per labor (rs)	-0.060	-0.079	-0.069	-0.063	-0.075	-0.093
	[0.065]	[0.064]	[0.064]	[0.063]	[0.064]	[0.065]
Licensed technology stock per labor (tl)	0.014***	0.014***	0.014***	0.013***	0.013***	0.013***
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]
R&D spillovers from FDI per labor (rs_{for})	0.004	0.004	0.004	0.003	0.003	0.003
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]
TC*in-house R&D stock per labor (r_tc)		0.022				
		[0.032]				
TC*Trade/Revenue (tr_tc)			0.002			
			[0.001]			
TC*R&D spillovers per labor (rs_tc)				0.021		
				[0.047]		
TC*R&D spillovers from FDI per labor (rs_{for}_tc)					0.016	
					[0.012]	
TC*Licensed technology stock per labor (tl_tc)						0.007
						[0.019]
Constant	6.428***	6.456***	6.635***	6.331***	6.197***	6.387***
	[0.753]	[0.705]	[0.737]	[0.731]	[0.743]	[0.734]
Hasen-Pv	0.181	0.242	0.267	0.281	0.188	0.197
AR1p	0	0	0	0	0	0
AR2p	0.628	0.569	0.774	0.613	0.458	0.446
Observations	9106	9106	9106	9106	9106	9106
Number of id	1695	1695	1695	1695	1695	1695

Table 4.12. Two Step GMM System Regression Analysis of Labor Productivity, Domestic Sample, 2003-2010

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
First Lag of labor productivity per labor (y_{t-1})	0.329***	0.328***	0.324***	0.326***	0.350***	0.328***
	[0.068]	[0.066]	[0.067]	[0.068]	[0.067]	[0.066]
Second Lag of labor productivity per labor (y_{t-2})	0.085***	0.082***	0.088***	0.086***	0.086***	0.085***
	[0.022]	[0.021]	[0.022]	[0.021]	[0.022]	[0.022]
Physical Capital stock per labor (k)	0.042***	0.044***	0.043***	0.045***	0.042***	0.043***
	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]
In house R&D stock per labor (r)	0.010	0.011	0.014*	0.011	0.008	0.012*
	[0.007]	[0.007]	[0.008]	[0.007]	[0.007]	[0.007]
Herfindahl index (herf)	0.376	0.485	0.377	0.374	0.392	0.479
	[0.648]	[0.638]	[0.636]	[0.621]	[0.625]	[0.640]
Trade/Revenue (tr)	0.003***	0.004***	0.003**	0.004***	0.003***	0.004***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Technological capability (tc)	0.025	-0.361	-0.156	0.515	-0.021	-0.191
	[0.110]	[0.382]	[0.152]	[0.607]	[0.115]	[0.201]
R&D spillovers per labor (rs)	-0.029	-0.043	-0.034	-0.037	-0.043	-0.047
	[0.071]	[0.069]	[0.070]	[0.067]	[0.070]	[0.071]
Licensed technology stock per labor (tl)	0.013***	0.013***	0.013***	0.013***	0.013***	0.012***
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]
R&D spillovers from FDI per labor (rs_{for})	0.004	0.003	0.003	0.004	0.004	0.003
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]
TC*in-house R&D stock per labor (r_tc)		0.038				
		[0.037]				
TC*Trade/Revenue (tr_tc)			0.003**			
			[0.002]			
TC*R&D spillovers per labor (rs_tc)				-0.034		
				[0.042]		
TC*R&D spillovers from FDI per labor (rs_{for}_tc)					0.012	
					[0.015]	
TC*Licensed technology stock per labor (tl_tc)						0.031
						[0.029]
Constant	5.826***	5.950***	5.935***	5.780***	5.687***	5.939***
	[0.831]	[0.772]	[0.817]	[0.791]	[0.791]	[0.796]
Hasen-Pv	0.259	0.368	0.382	0.304	0.359	0.321
AR1p	0	0	0	0	0	0
AR2p	0.381	0.327	0.457	0.398	0.285	0.377
Observations	8104	8104	8104	8104	8104	8104
Number of id	1514	1514	1514	1514	1514	1514

Even though the results of the two-step system GMM for all firms and domestic firms seem to be quite similar, the most important insight that this analysis provides is that in-house R&D is more important for domestic firms and technological capability has an impact on the trade performance of domestic firms. However, we cannot use the parameter of this variable as an indicator of its average impact on productivity because of the presence of the interaction terms. To find the impacts of the marginal variables with interaction terms we have computed their marginal effects at three different levels of technological capability; average level, minimum level and maximum level . Results are provided in Tables 4.11 and 4.12. For example, the marginal effect of in house R&D stock per labor given the technological capability – using the results obtained from Equation 4.5- has been calculated as follows:

$$\frac{\partial E\left[y_{it} \left| r_{it} tc_{it} \right. \right]}{\partial r_{it}} = \alpha_2 + \alpha_{10} tc^* \tag{4.6}$$

where all the variables are as defined before and tc* is the minimum, average or the maximum value of technological capability in the sample.

Equation 4.6 implies that the marginal effect of higher level of R&D stock per labor on labor productivity per labor is increased when the technological capability is higher. The sample mean is the natural choice for the interaction term (i.e. technological capability in our case). However, we have calculated the marginal effects at three different levels of technological capability (i.e. mean, minimum and maximum) in order to find out the impact the level of technological capability of firms together with the knowledge diffusion channels have on their level of productivity. The results of the marginal effects of knowledge diffusion channels on labor productivity are provided in Table 4.13.[143]

Ülkü and Pamukçu (2015) found that within firms with average technological capability a 1 % increase in in-house R&D intensity leads to about a 0.3 % increase in labor productivity in both full sample and domestic sample. The impact of in-house R&D stock on labor productivity increased within firms with maximum technological capability, a 0.43 % and 0.50 % increase in the full sample and the sample of domestic firms, respectively. In terms of in-house R&D intensity our results indicate that a 1% increase of in-house R&D stock per labor leads to about a 0.01% increase in labor productivity within firms with average technological capability in the domestic sample (see Table 4.13). From the fall in the number of both domestic and foreign R&D conducting firms (provided in Table 4.3) after 2008 we could expect that our results would somewhat differ from Ülkü and Pamukçu (2015) but we did not expect it to be as strong as this. Our result on in-house R&D indicates that not only has the number of firms engaged in R&D decreased after 2008 global crisis, this crisis also had an important impact on the in-house R&D structure of the firms remaining in the manufacturing sector. However, our result on the domestic sample suggests that the technological capabilities of firms determine their ability to use R&D stock effectively to promote productivity, as has been emphasized by Gerschenkron (1962) and Cohen and Levinthal (1990).

In terms of industry level R&D spillovers Ülkü and Pamukçu (2015) found a significant negative impact on productivity among firms with lowest technological capability and positive among firms with maximum technological capability, in both full sample and domestic sample. This result indicates that firms with higher absorptive capacity are more likely to benefit from knowledge diffusion. In our analysis the industry level R&D spillovers are statistically insignificant (see Table 4.13).

[143] We have computed the marginal effects using the nlcom command in stata.

Ülkü and Pamukçu (2015) found that R&D spillovers from foreign firms in the same industry -as in the case of industry level R&D spillovers – had positive impact on productivity only for firms with high level of technological capability, in both the full sample and the domestic sample of firms. In our analysis the R&D spillovers from foreign firms are also statistically insignificant (see Table 4.13). Thus, compared to Ülkü and Pamukçu (2015) R&D spillovers and R&D spillovers from foreign firms have no significant impact on productivity at all three levels of technological capability in both full and domestic samples. These result may suggest that in terms of R&D the manufacturing sector has been seriously affected from the 2008 global crisis and that R&D activities of the firms in the Turkish manufacturing sector seems to be sensitive to external shocks.

Ülkü and Pamukçu (2015) found that technology licensing increased the productivity of firms with average and higher technological capability. The impact technology licensing was higher on the productivity of domestic firms compared to the full sample. As can be seen from Table 4.13, in our analysis technology licensing increased the productivity of firms with average and lower technological capability in both domestic and full sample. We found that within firms with average and minimum technological capability a 1 % increase in licensed technology leads to about a 0.01 % increase in labor productivity in both full sample and domestic sample.

Another important difference between our and Ülkü and Pamukçu (2015) results is that while international trade has no significant impact on productivity at any level of technological capability in either sample of Ülkü and Pamukçu (2015), in our analysis it seems to have impact on productivity at all levels of technological capability in both samples. As can be seen from Table 4.13 in both the full sample and the domestic sample of firms, a 1% increase in international trade leads to about a 0.003% increase in labor productivity of firms with average and minimum technological capability and roughly 0.01% increase within firms with maximum technological capability. These results indicate that firms with higher technological capability due to their higher absorptive capacity are more likely to benefit from knowledge diffusions via international trade.

4.4. Conclusion

In this essay our aim was to investigate the impact of knowledge indicators on the productivity of firms in the Turkish manufacturing sector during the 2003-2010 period.

As mentioned before, to our knowledge, there are only few studies that have investigated the relationship between the various dimensions of knowledge and the productivity of firms in the Turkish manufacturing sector. The most recent study on the Turkish manufacturing sector is by Ülkü and Pamukçu (2015), who have investigated the impact of R&D and knowledge diffusion channels on the productivity of the Turkish manufacturing firms during the 2003-2007 period. The results of this study indicate that an increase in R&D intensity leads to increase in the productivity levels of firms with technological capability that is similar to the threshold technological capability level. That is, the level of technological capability of firms determines both their ability to use the available R&D knowledge and their ability to undertake new R&D activities.

In our essay we attempt to take Ülkü and Pamukçu's (2015) study one step further by utilizing a more comprehensive dataset both in terms of scope and time dimension. This dataset was established by using three different datasets (the Industry and Service Statistics database, the Foreign Trade database and the R&D database) of TurkStat, for the 2003-2010 period. As indicated previously this is an important departure from Ülkü and Pamukçu (2015) since in our analysis we used R&D data that is compiled according to the Frascati Manual. Our second departure is the length of the time period of our dataset which contains data from 2003 to 2010.

Table 4.13. Marginal Effects of Interaction Terms on Labor Productivity

	Full			Domestic		
VARIABLES	Min	Mean	Max	Min	Mean	Max
Trade/Revenue	0.003***	0.003***	0.012**	0.003**	0.003***	0.016**
	[0.001]	[0.001]	[0.005]	[0.001]	[0.001]	[0.006]
R&D spillovers per labor	-0.063	-0.062	0.025	-0.037	-0.038	-0.179
	[0.063]	[0.063]	[0.204]	[0.067]	[0.067]	[0.202]
Licensed technology stock per labor	0.013***	0.014***	0.041	0.012***	0.013***	0.141
	[0.004]	[0.004]	[0.080]	[0.004]	[0.004]	[0.120]
R&D spillovers from FDI per labor	0.003	0.003	0.069	0.004	0.004	0.054
	[0.004]	[0.004]	[0.051]	[0.004]	[0.004]	[0.064]
In-house R&D stock per labor	0.009	0.009	0.101	0.011	0.012*	0.169
	[0.007]	[0.007]	[0.136]	[0.007]	[0.007]	[0.157]

Standard errors in brackets *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The results of our essay supports the findings of Ülkü and Pamukçu (2015) with regards the importance of physical capital stock, in-house R&D stock, the level of market concentration, trade, technological capability and foreign ownership as the determinants of R&D activities of the manufacturing firms in Turkey. Our results also point technological capability as an important determinant of the firm's ability to use the available R&D in the industry. The most important divergence between our and Ülkü and Pamukçu's (2015) estimation results is that, in our results in-house R&D, R&D spillovers and R&D spillovers from foreign firms have no significant impact on productivity at all three (minimum, mean and maximum) levels of technological capability in both full and domestic samples. This result reflects that there is problem with regards R&D investment in the Turkish manufacturing sector. Since the time dimension of our dataset is extended to 2010, our results may be interpreted as containing the adverse effects of global financial crisis and increasing international competition on the R&D investment efforts of firms in the Turkish manufacturing sector.

Nevertheless, while formalizing policies for enhancing the competitiveness of the manufacturing sector, the policy makers should consider the needs of each sub-sector separately because they vary substantially in terms of both physical and technological structure.

CHAPTER 5

CONCLUSION AND POLICY RECOMMENDATIONS

In this Ph.D. thesis we have investigated the role of knowledge on economic growth both at macro and micro levels in a three distinct but complementary essays.

The first essay was a multi-country analysis, in which we investigated the impact of knowledge indicators on economic growth performances of the OECD member countries using panel data from 1995 to 2011. Additionally, this essay attempted to analyze the role of knowledge indicators on the catch-up efforts of the follower member countries in OECD. In the first part of the essay, we developed an augmented model using Benhabib and Spiegel's (1994) specification (see Figure 5.1). To our surprise the econometric results of our augmented model contradicted the theoretical expectations. That is, majority of the results of our panel data estimation with the traditional techniques (e.g. fixed effects model) were either theoretically inconsistent or statistically insignificant. When we deepened our investigation we found that there were serious limitations of the specification used by Benhabib and Spiegel (1994). In their model Benhabib and Spiegel (1994) followed Nelson and Phelps (1966), who have emphasized role of human capital in adaptation of new technology and hence improving total factor productivity. Thus, human capital enters the model only via total factor productivity. So, accordingly in our specification we followed this line of reasoning and hence introduced the knowledge indicators into our model through total factor productivity.

However, later we found out that when human capital enters the model as an additional input of production it captures the role of human capital accumulation in the growth process (Lucas, 1988). Thus, we developed another model - the augmented knowledge production function - where we introduced human capital as an additional input together with capital stock and also included the other critical knowledge variables as shift factors in the production function. Moreover, in this analysis we also utilized dynamic panel data techniques, which are more suitable for macro panel data, and this provided us the opportunity to utilize the long-run information in the data by focusing on the equilibrium relations. Accordingly, Peseran et al. (1999) we used PMG estimator where only the long run coefficients are same across countries and the short run coefficients vary. One advantage of PMG method is that it takes into account non-stationarity as well as cointegration that are commonly observed in macroeconomic analysis, with panel data where there is large number of countries over short period of time. Estimation results of this model were both theoretically and statistically significant. That is, our results indicated that knowledge variables as a whole had positive impact on the economic growth performances of OECD countries and the OECD members seemed to be converging to a common long-run equilibrium represented by the augmented knowledge production function.

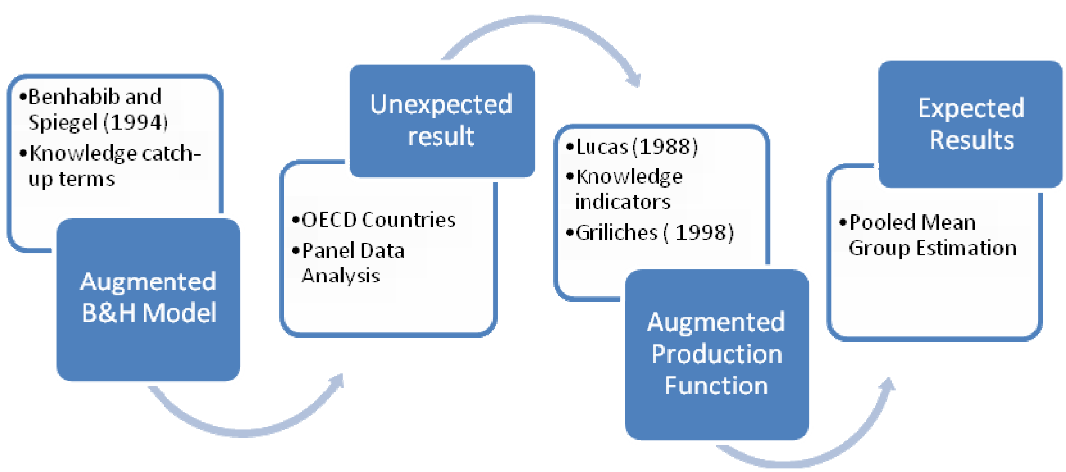

Figure 5.1. An Overview of Essay 1

In the second essay we analyzed the impact of knowledge on the economic growth performance of Turkey over the 1963-2010 period, by using a production function approach. As can be seen from Figure 5.2, first, we developed a production function model by considering the seminal studies on different strands of endogenous growth models that have focused on various dimensions of knowledge. To see the impact of various dimensions of knowledge with a single and comprehensive measure of the "level" of knowledge in the economy we constructed a knowledge index (KNIW). The construction of a knowledge index not only provided us with a composite and useful measure of the "level" of knowledge, but it also prevented the potential problem of multicollinearity due to the high level of correlation between the knowledge variables. Then, time series methods, such as cointegration and impulse response analysis were used to analyze the role of knowledge on economic growth in Turkey over the 1963-2010 period.

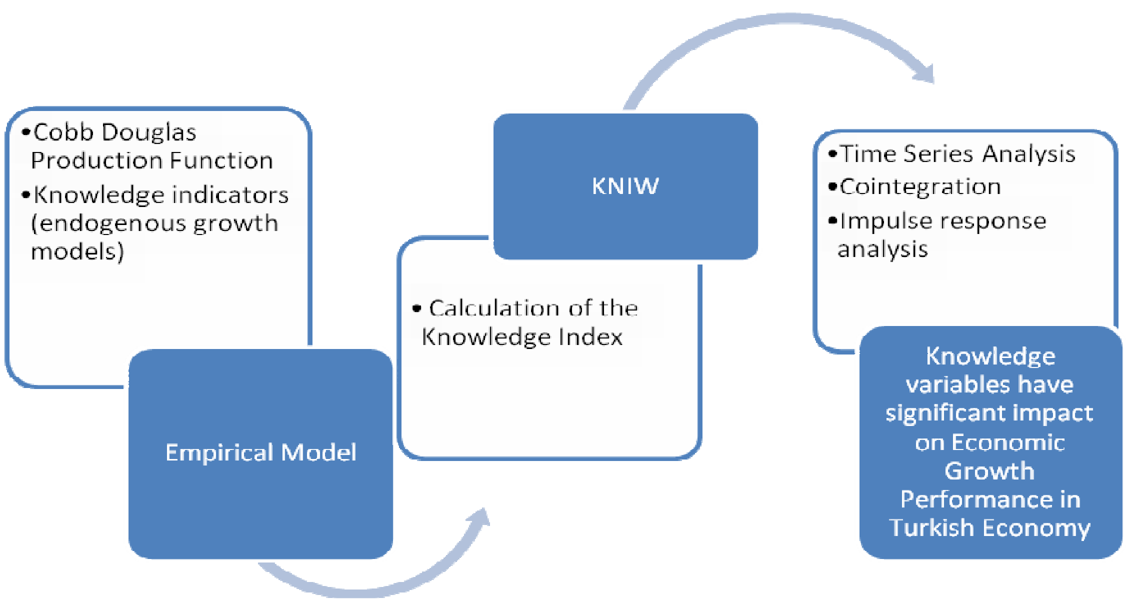

Figure 5.2. An Overview of Essay 2

Overall the empirical results indicated that higher level of knowledge had a positive and statistically significant impact on the growth rate of Turkish economy over the sample period.

In the last essay, we investigated the impact of knowledge indicators on the productivity levels of manufacturing firms in Turkey, by using firm level panel data from 2003 to 2010.

This essay consisted of two parts. As can be observed from Figure 5.3, in the first part we utilized the model developed by Ülkü and Pamukçu (2015) to investigate the impact of R&D and knowledge diffusion channels on the productivity of the manufacturing firms in Turkey during the 2003-2010 period.

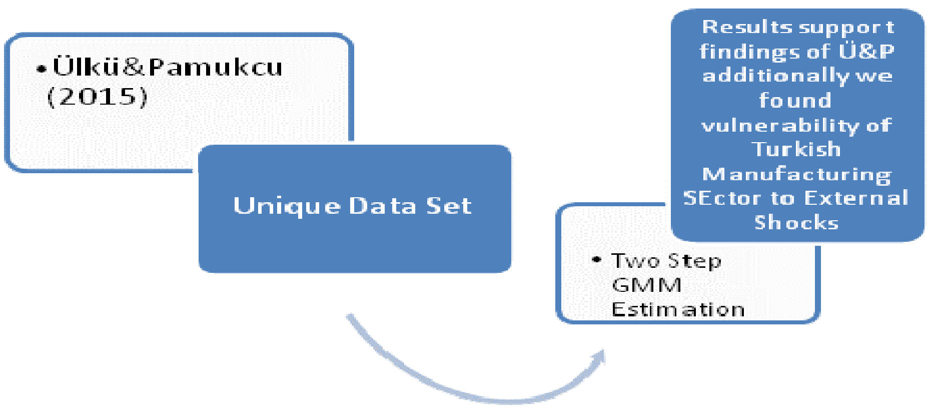

Figure 5.3. An Overview of Essay 3

The empirical results of this analysis supported the findings of Ülkü and Pamukçu (2015) with regards the importance of physical capital stock, in-house R&D stock, the level of market concentration, trade, technological capability and foreign ownership as the determinants of R&D activities of the manufacturing firms in Turkey. Our results also underline the importance of technological capability as a determinant of the firm's ability to use the existing R&D in the industry and engage in R&D activities.

Policy Implications

As indicated before, the aim of this thesis was to investigate the role of knowledge on productivity and economic growth. The results of all three essays have shown that the knowledge pillars (indicators) contribute to the growth performances and catch up efforts of countries and firms (albeit at different extent). These pillars both shape and determine the level of the knowledge in the given economy.

Even though, based on the result of the three essays we will present our policy recommendations at macro, meso and micro levels, it is important to underline that in terms of knowledge pillars the lines between these three levels can sometimes be very blurry and a policy recommendation mentioned at one level can easily be applied at the other extreme level.

In terms of the pillars of knowledge investigated in this thesis and economic growth our main **macro (national) level** policy recommendations are:

- ***Tailor Made Policies:*** Our results indicate that knowledge variables are important for economic growth, but there is substantial variance as to how much of the available knowledge countries can utilize to enhance their growth performance. As we have seen in our cross country analysis, countries are heterogeneous in their structures and this heterogeneity determines their ability to use available knowledge pillars efficiently and their catch-up capability. Thus, rather than taking the short cut and implement a policy that has had successful outcomes for another country, it is important to choose the longer method by starting to analyze thoroughly the specific country conditions and try to tailor policies that would answer the specific needs of the country in question.

Moreover, in Essay 1 we saw that the follower country can catch-up with the leader country/countries only if the initial gap between them is not too wide, otherwise countries end up in a catch-up trap. That is, in the long-run countries reach similar steady states only when they have similar structures, such as, institutional structure, economic structure, quality of human capital and so on. These conditions are the main determinants of social and absorptive capabilities. Thus, convergence is much easier among countries with similar social and absorptive capabilities.[144]

Therefore, the policy maker should be aware that the *heterogeneity* among the capabilities of countries *requires special policies* that targeted to the needs of the country in question; there is no standard policy that is available to all countries.[145] This is especially relevant for developing countries that have no luxury to experiment with their limited resources. Thus, rather than targeting the "edge" technological frontiers, policy makers should carefully evaluate the capabilities of the economy and the society and accordingly formulate policy measures that aim the most appropriate technological frontier.[146]

Thus, policy makers should first map the existing capabilities of the country/industry. While mapping the existing capabilities the policy makers should give priority to the analysis of the quality of the workforce, the structure of the existing infrastructure[147] and the capabilities of public sector institutions in supporting and promoting the diffusion of critical technologies. Once the policy maker has a detailed and thorough analysis on the capabilities of the country, then he/she can introduce policy measures that are targeted to specific needs that use the available resources effectively and efficiently. But, to ensure that in the long run higher economic growth level is achieved, the policy maker has to continuously monitor and assess the policy measures and if necessary make the necessary changes and updates.

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[144] See, for example, Jovanovic (1998) and Hobijn (2001) for more detail. Similarly Basu and Weil (1998) with their appropriate technology model argue that new technologies can only be implemented successfully by countries with appropriate endowments.

[145] See for example, Rodrick and Subramanian (2003) getting diagnostics right.

[146]For example, as argued in Essay 1 the technological frontier that the country tried to catch-up was determined by their income group. That is, while the middle income group countries could targeted the technological frontiers of the higher income countries in the case of the lower income countries, with their existing economic structure and absorptive capabilities it was more appropriate for them to target the technological frontiers of the middle income countries.

[147] That is, what type of technologies can be used, create and expand with the existing infrastructure.

- ***<u>Availability and Quality of Data:</u>*** The most important limitations that we have experienced in all three essays were related to the availability and the quality of data. For instance, the main reason for selecting OECD member countries in Essay 1 was related to availability of relatively more dependable, concise and comparable data for knowledge indicators for most of the countries. Even so, we have experienced difficulties in obtaining data especially of late joining former Soviet Union states (e.g. Slovenia). In the second essay we had use patents as a proxy R&D due to the lack of data of data on R&D expenditure in Turkey for the 1963-2010 period. In the last essay, in the TurkStat survey that we were utilizing there was no direct data on the number of computers. Thus, we had to use software expenditure of firms as a proxy for ICT.

Thus, in order to formulate realistic and dependable policies, policy makers must give priority *to compiling and increasing the quality of data*. Because, the quality of data that is being used determines the accuracy of the information with respect to the present situation in terms of knowledge indicators and the determination of efficient and effective policy tools that contributes to the increase of the knowledge capital. In terms of the Turkish data, time series data on R&D expenditure and data on ICT variables both at macro and micro level have to be updated and re-organized with more detailed information (for example, number of computers that the firm owns).

- ***<u>Human Capital is the "Engine" of Knowledge Economy</u>***: Our results also indicate that, in terms of direct and indirect effects, human capital can be considered as the most important knowledge pillar. This verifies the argument put forward by Mincer (1958), Becker (1962) and Forray (2004) who place human capital at the center of knowledge accumulation. The human capital determines the efficient and effective outcome of the other knowledge indicators; available knowledge can be fully utilized only when we have human capital that can digest it, thus quality of human capital is important; and last but not least the quality of the human capital is the main determinant the technological capability of countries.

The results of the first two essays (cross country and country specific) points human capital as the important factor for the observed differences of the economic growth between OECD countries and the contributor to the growth performance of Turkey during the 1963-2010 period.[148] In the cross country analysis we have seen that the ability to adopt and initially to imitate the technology of the leading country depends on the quality of the human capital, which is a fundamental part of the absorptive capacity.

In the third essay we found human capital to be the most important determinant that shaped the catch-up ability of the lagging firms. At the firm level, the prerequisite of R&D is qualified human capital, which shapes the R&D capabilities of firms. Thus, the quality of the human capital determines the R&D ability of both firms and countries. Moreover, we have found that it played a major part in "catch-up trap".

All these results indicate that the impact of knowledge on economic growth is primarily determined by the existing structure of human capital. In other words it could be said that at the core of knowledge accumulation is human capital.

Therefore, in line with our results, our first policy recommendation concerns the improvement of the quality of human capital. But policies aiming to accomplish this should not be bounded by simple policy targets such as increasing "school enrollment rates" which is an indicator of basic education. Without any doubt basic education increases the capacity to learn and to use information however it is not enough to understand the advanced and complicated structure of the edge technologies of today.

In order to catch-up with the leading technologies at international level, a country needs a human capital with higher education in engineering and scientific areas. Programs that encourage universities to establish international exchange links will play a crucial role in enhancing international spillovers to the domestic economies. Therefore, policy makers should attribute importance to building a strong higher

[148]See, for example Nelson and Phelps (1966), Romer (1990) and Islam et al. (2011).

education system that supports the technology sectors and take initiatives to build an educational exchange networks with countries in the technological frontier.

The results of our sector specific analysis on the Turkish manufacturing sector (Essay 3) indicate that it is also important to increase the number and quality of qualified workers. The successful growth performance of the East Asian countries during the 1990s is a good indicator of the importance of technical secondary level education that makes it possible for workers to adopt and imitate the transferred technology. This can be attained by increasing the number of graduates from technical secondary level with qualifications that will ensure that they have the background to adopt and imitate the transferred technology. However, firms can also play important role in provision of human capital. Thus, measures[149] that encourage firms to train their own workers should be incorporated in policies.

However, since the outcomes of these policies will be realized in the long run, in the short-run priority should be given to decreasing brain drain and present incentives for researchers that are working in other countries to return. After determining the targeted sectors policy makers can also establish policies that are geared with incentives to attract foreign researchers.

- ***<u>Identifying the Core Institutions:</u>*** Policy makers have to identify the institutions that need to be established or improved for an environment that plays active role for the efficient use of knowledge pillars.

Every country is unique, so a policy that was successful in one country might not work in another. At the end it is the country specific characteristics, especially institutional structure determines the outcome. This is nicely summarized by well-known economist Elhanan Helpman:

> Countries that start with similar endowments can follow different developmental paths as a result of differences in institutional structures, because institutions affect the incentives to innovate and to develop new technologies, the incentives to reorganize production and distribution in order

[149] These measures can be tax incentives and financial support paid directly to firms or cooperation among firms or universities can be supported.

> to exploit new opportunities, and the incentives to accumulate physical and human capital. For these reasons institutions are more fundamental determinants of economic growth than R&D or capital accumulation, human or physical. …[T]he ability of a country to grow also depends on its ability to accommodate … changes [e.g. technological changes], and the ability to accommodate change depends in turn on a country's economic and political institutions. … The institutions that are good for one period are not necessarily good for another (Helpman, 2004:139-140).

- ***Physical Infrastructure*****:** The results of Essay 2 indicate that building an efficiently operating ICTs infrastructure contributes to the long-run economic growth performances of countries. Especially, in the era that we are living in, information and communication technologies are vital in order to make use of the readily available information and spillovers of existing information both at firm and country level.

Nearly all of the edge technologies are based on information technologies, such as computers. Moreover, the communication technologies help us to keep up with the recent developments in the industrial countries instantly and contribute to building an up to date knowledge base. We have seen that some aspects of ICTs, such as internet, require serious investment infrastructural investment that is difficult especially for low income countries to finance. However, with relatively low usage costs and the ability to overcome distance, ICTs are the most efficient means to transfer information and knowledge around the world. The best part of ICT is that it presents variety of alternatives to transfer information. Policy makers, especially in the low income countries, for example, can utilize mobile phone technology to build an information (internet) system.

Moreover, building or increasing technological capabilities requires physical infrastructure that can accommodate the targeted research area (for example, industrial research), technology transfer and so on. Thus, policy makers should give priority to building an efficiently operating ICTs infrastructure.

The **meso (industry) level policy** recommendations that we developed from the results of this thesis are:

- ***Determination of the feasible technological frontier:*** From the results of Essay 1 we saw that the technological frontier varied according to the level of income of countries so that policies are based on realistic grounds. After determining the most feasible technology frontier, policy makers should formulate means to strengthen technological capabilities according to the requirements of this area.

- ***Promoting Internal and External Network Connections:*** Policy makers should invest in building a strong network among the universities and research agencies and take initiatives to build an educational exchange networks with countries in the technological frontier. For example, Israel supported the high-tech sector with one of the finest university systems in the world and priority has been also given to the educational exchange links developed with technologically leading countries such as the United States in academic and software development (Berry, 2002).

Therefore policy measures should include subsidies that aim to promote to increase collaboration, especially R&D activities between the private sector and universities. Some country specific examples indicate that having universities that can engage in R&D activities and support the private sector with their findings increases the growth performance of economies.

Centers of technology (for example, techno parks) are other important institutions where exchange of knowledge among the above mentioned institutions takes place. The policy makers should also provide financial support and/or incentives that would promote cooperation among different organizations.

The **micro (firm) level policy** recommendations that we developed from the results of this thesis are:

• ***Support highly qualified researchers***: Universities and research centers should be supported with various types of incentives to increase the capabilities of their researchers. In order to enhance their initial human capital base, research institutes should be encouraged to provide opportunities for their researchers to improve their skills and knowledge capabilities by attending national and international training programs. In addition to increasing the human capital capabilities this will also provide opportunity for the researchers to increase their network connections, which will contribute to the knowledge accumulation in the research center.

Research centers can also increase their knowledge capacity by encourage research centers to recruit highly qualified domestic or foreign researchers.

• ***Support Foreign R&D Investment***: In order to attract foreign investment, such as FDI, apart from economic conditions[150], technological and scientific capabilities, political stability and public infrastructure are important factors that should be overviewed and if necessary revised.

As mentioned previously, one of the main determinants of foreign investment in the R&D sector is the technological and scientific capability. These capabilities are in turn shaped by the level of qualified human capital, available research base (both academic and industrial), intellectual property rights and so on. Apart from enhancing foreign investment improving these factors would also contribute to the development of domestic firms or domestic R&D centers.

In terms of *R&D capabilities* policy makers can enhance it by providing support to both public and private research institutions and ensure that there is an appropriate policy environment that supports R&D activities.

Moreover, R&D requires, educated human capital base and efficiently operating institutional infrastructure. For example, public and private research institutions require appropriate policy environment that supports their R&D activities. For

[150] For example, market size, tax incentives and labor market conditions.

example, adequate protection and enforcement of intellectual property rights increases the incentive of researchers and scientists to engage in R&D activities. Thus, securing the rights of the innovators is another important issue that the policy maker should give priority.

Once a strong R&D base is established a country can increase its innovative capability that would in turn increases the competitive power and the economic growth potential of the country.

- ***Improve coordination and cooperation among different actors in the economy:*** Coordination and cooperation among the different public and private institutes is important for successful implementation and outcome of policies. The interaction among the different actors in the economy can contribute to enhancing the available knowledge stock in the industry in question. Thus policy makers should embody measures that promote collaboration among different parties.

- ***Reduction of Administrative Burdens in International Cooperations:*** Red tape bureaucracy and other types of administrative burdens are common burdens for beneficiaries of public supported policies. Thus, decreasing burdens would encourage international cooperation activities for both firms and research centers.

In sum, access to knowledge by itself is not enough for economic growth. In the bottom line the "absorptive capacity" and "social capability" of countries determine the impact of the acquired knowledge on economic growth and catch-up process of countries. Developing capabilities is a long run process and that catch-up process is very difficult, especially for very low levels of income groups. Therefore, patience and continuous monitoring, evaluation and revision of policies are the key for increasing both the adaptive and social capabilities.

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APPENDICES

Appendix 2.A. OECD Countries

Table 2A.1. List of OECD Countries

COUNTRY	Ratification of the Convention on the OECD
Australia	7 June 1971
Austria	29 September 1961
Belgium	13 September 1961
Canada	10 April 1961
Chile	7 May 2010
Czech republic	21 December 1995
Denmark	30 May 1961
Estonia	9 December 2010
Finland	28 January 1969
France	7 August 1961
Germany	27 September 1961
Greece	27 September 1961
Hungary	7 May 1996
Iceland	5 June 1961
Ireland	17 August 1961
Israel	7 September 2010
Italy	29 March 1962
Japan	28 April 1964
Korea	12 December 1996
Luxembourg	7 December 1961
Mexico	18 May 1994
Netherlands	13 November 1961
New Zealand	29 May 1973
Norway	4 July 1961
Poland	22 November 1996
Portugal	4 August 1961
Slovak republic	14 December 2000
Slovenia	21 July 2010
Spain	3 August 1961
Sweden	28 September 1961
Switzerland	28 September 1961
Turkey	2 August 1961
United kingdom	2 May 1961
United states	12 April 1961

Appendix 2.B. Level vs. Difference Form Specification

In this appendix section we provide the empirical analysis in level form (y and k enter in their levels rather in difference form, Δy and Δk).

Table 2A.2. Results of Level Panel Data Analysis (y)

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Log of Per Capita Capital (k)	0.6442*** [0.0846]	0.4084*** [0.1008]	0.6478*** [0.0981]	0.3089*** [0.0864]	0.5296*** [0.0869]	0.2849*** [0.0937]
Human Capital (h)		17.3177* [8.9438]				1.3531 [6.588]
Human Capital Catch-up (C_h)		-5.26087*** [0.7621]				-4.4850*** [0.9662]
R&D Stock (R)			0.000011** [0.000004]			0.000015*** [0.000002]
R&D Stock Catch-up (C_R)			-0.000043 [0.000041]			0.000006 [0.000020]
Internet (I)				0.096375*** [0.028538]		0.062131* [0.034743]
Internet Catch-up (C_I)				0.101174*** [0.028686]		0.049799** [0.022619]
Openness (O)					0.177560* [0.100980]	0.059206 [0.039833]
Openness Catch-up (C_O)					-0.0599*** [0.019008]	0.007758 [0.013610]
Constant	1,697.3*** [101.374]	1,946.1*** [101.298]	1,692.8*** [115.966]	2,091.6*** [102.257]	1,825.1*** [100.855]	2,126.9*** [109.979]
Obs.	578	578	578	578	578	578
R-squared	0.710	0.828	0.715	0.788	0.767	0.862
Country	34	34	34	34	34	34

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

As can be seen from Table 2A.2 capital stock variable (k) is statistically significant in all models. All knowledge indicators are both theoretically consistent and statistically significant when they are introduced to the analysis on their own (Model 2-5). However, in the fully specified model (Model 6) only R&D stock and ICT is theoretically and statistically significant.

Even though level form specification provides better estimation result compared to the difference form specification, these results are not directly comparable and require careful interpretation. We will take up this issue at the end of Section 2.4.3.

Appendix 3A. Science and Technology Policies in Turkey

The Science Technology and Innovation Policies (STIPs) in Turkey became more apparent with the start of the planned economy period during the 1960s. The first five year plan contained a section on research and 0.4% of GDP was foreseen for R&D expenditures. The main objective was to increase the number of researchers engaged in R&D through promoting research activities and establishing a scientific and technical research council. In line with this new strategy, in 1963, the Turkish Scientific and Technological Research Council (TSTRC (i.e. TÜBİTAK)) was established to develop the science, technology and innovation policies and since then it has been coordinating, organizing and promoting and developing the basic and applied research and technological developments in Turkey. During this period research was mainly conducted in mineral and agricultural industries by universities and state research institutes.

During the 1980s the most important development in STIP was the establishment of the Supreme Council for Science and Technology (SCST)[151] with decree number 77 on the 4th of October 1983. According to this decree the SCST is to meet twice annually and its duty is to assist the government; in determining long term science and technological policies; determining targets; determining priority areas; preparation of plans and programs; appoint government establishments; cooperation with private organizations; preparation of necessary legal and regulatory documents; ensure that researchers are trained; take incentives for the establishment of private research institutions; and ensure the coordinator between the sectors and the establishments. However it took seven years for it to meet for the first time in 1989, met for the second time four year later (1993) and five years later for the third time (1998). From 1983 to 2002 in the total it met for 7 times.

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[151] The SCST meets under the chair of the Prime Minister or deputy Prime Minister, with the attendance of related 10-12 Ministers and high rank officials.

In terms of STIP the most important developments during the 1990s was the establishment of Turkish Academy of Sciences, in 1993, that was established with the aim to bring increase scientific research and ensure that social strategies are defined under scientific principles are technological data. A year later in 1994 the Turkish Patent Institute was established. In 1995, Scientific and Technological Research Council started funding industrial R&D projects of large firms and SMEs, this is still the most important public R&D incentive programme in Turkey. This programme is coordinated by Technology and Innovation Support Programs Directorate (TISPD/TEYDEB). Under this programme support is given to; machinery and manufacturing technologies; electrical and electronics; information technologies; materials, metallurgical and chemical technologies; and biotechnology, agriculture, environmental and food technologies. When the project applications are analyzed we see that machinery (approximately 30%), information technologies (approximately 20%) and electrical and electronics (16%) are the leading fields.

As can be seen from Table 3A.1 between the 1995-2011 out of the total of 13.604 project applications (73% SMEs and 27% large firms) 8.371 projects (70% SMEs and 30% large firms) were supported and the total of the fund was 2.5 billion TL. The share of the SMEs applying for the projects has increased from 49% (1995-2001 period) to 79% (2007-2011 period). Later on in 2012 two additional programs were launched to support the R&D starters.[152]

Another important development in the late 1990s was that the SCST started to meet every single year and has started to play a more effective role in the establishment and implementation of the Turkish STIPs. Recently the SCST has held its 28th meeting on the 6th of January 2015.

The SCST during the 1993-2003 period gave priority to ICTs and biotechnology, and with the Science and Technology Leap Project set out the goals and measures

[152] The 1507 SME R&D Support Program (2012) and the 1511 Priority Areas Research Technological Development and Innovation Support Program.

to be taken. The aim of this project was to establish a national innovation system that would ensure an environment where the new science and technologies produced are instantly transformed into economic and social wealth.

Table 3A.1 Project Applications between the 1995-2011 period

	SMEs	Large Firms	Total
Project Application	10747 (73%)	2857 (27%)	13.604 (100%)
Supported Project	5860 (70%)	2511 (30%)	8.371 (100%)
Firms Supported	3529 (89%)	436 (11%)	3.965 (100%)
Amount of Fund	₺1.214 billion (49%)	₺1.286 billion (51%)	₺2.5 billion (100%)

Source: Calculated by the author using the TUBITAK data.

In 1997, by SCST, once again these targets were introduced in detail under the Science and Technology Policy of Turkey and decided to be included in the Implementation Agenda. This agenda underlined the priority of establishing an effectively operating national innovation system. The state was to reorganize national funds especially the public funds according to the prioritized areas in the policies. Moreover, the state was to ensure the interaction and harmony between the different actors taking part in the process. Thus, during the late 1990s and early 2000s gave priority to the establishment of infrastructural components of national innovation system, such as; national information infrastructure; national academic network and information center; electronic commercial network; law on the technology development regions; legislations on prevention of brain drain; national R&D budget; university-industry research centers; and supporting patent and other trademarks. The programs that have been introduced and the type of supports that has been provided by them have been summarized in Table 3A.2.

Table 3A.2 Technology and Innovation Support Programs Directorate R&D Support Programs

<table>
<tr><th>Type of Support</th><th colspan="2">Name of the Support Program</th></tr>
<tr><td rowspan="4">Venture Starters</td><td>1503 Project Market Support Program (2001)</td><td rowspan="12">1601 Innovation and Venture Capacity Building Support Program (2007)</td></tr>
<tr><td>1512 Individual Venture Support Program (2012)</td></tr>
<tr><td>1513 Technology Transfer Support Program (2012)</td></tr>
<tr><td>1514 Venture Capital Support Program (2012)</td></tr>
<tr><td rowspan="2">R&D</td><td>1505University-Industry Collaboration Support Program (2012)</td></tr>
<tr><td>1515 R&D Laboratory Support Program (2014)</td></tr>
<tr><td rowspan="3">R&D Starter</td><td>1501 Industrial R&D Support Program (1995)</td></tr>
<tr><td>1507 SME R&D Support Program (2012)</td></tr>
<tr><td>1511Priority Areas Research Technological Development and Innovation Support Program (2012)</td></tr>
<tr><td>International R&D</td><td>1509 International Industrial R&D Support Program (2007)</td></tr>
</table>

Source: Compiled by the author using information on the Support Programs of TUBITAK.

The share of R&D in GDP has steadily increased, as can be seen from Figure 3.4, it has increased from 0.54% (2001) to 0.95% (2013) during the last decade.

The Law on Support of Research and Development Activities has entered into force in April 2008. This law outlines the conditions that R&D centers must fulfill in order to benefit from incentives. For example, a R&D center must have at least 50 employees to qualify for the incentives, if there more than 500 researchers then 100% of the R&D expenditures are dropped from the taxable income, decrease of 50% of social security premiums for the employer for a period of 5 years, and so on. All the incentives under this law encourages R&D centers to employ more researchers and engage in R&D activities. Until 2012, 134 enterprises out of the 163 enterprises that have applied have been granted R&D Center Certificate. Currently 129 of these centers are active. The distribution of these centers is presented in Table 3A.3. As can be seen with 28.7% share the majority of the R&D centers are from automotive supply industry followed by ICTs industries (10.1%).

Table 3A.3. Distribution of R&D Centers

Sector	Share (%)
Automotive supply industry	28.7 %
ICTs	10.1 %
Automotive	9.3 %
Defense	9.3 %
Durable Consumer Goods	9.3 %
Electric and Electronics	7.8 %
Chemistry	6.2 %
Others	19.3 %

Source: Ministry of Science, Industry and Technology.

In 2010, the National Science Technology and Innovation Strategy (2011-2016) was accepted by the SCST. This strategy aimed to improve the human resources engaged in science, technology and innovation; support the transfer of R&D results into commercial products and services; support the SMEs so that they could become stronger actors in the innovation system; and activate the R&D infrastructure and international cooperation in science, technology and innovation. The main sectors automobile, machine and production technologies, ICTs, energy, water, food, security and space sectors were the main targeted sectors. The 2009 investment incentive package was revised in 2012. The revised incentive package contains supports for clusters, support for technology transition.

When we analyze the distribution of the financing of R&D expenditure we see that, in 2013, the commercial sector with a 47.5% has financed the largest share of R&D followed by Universities (42.1%) and public sector (10.4%) (see Figure 3A.1).

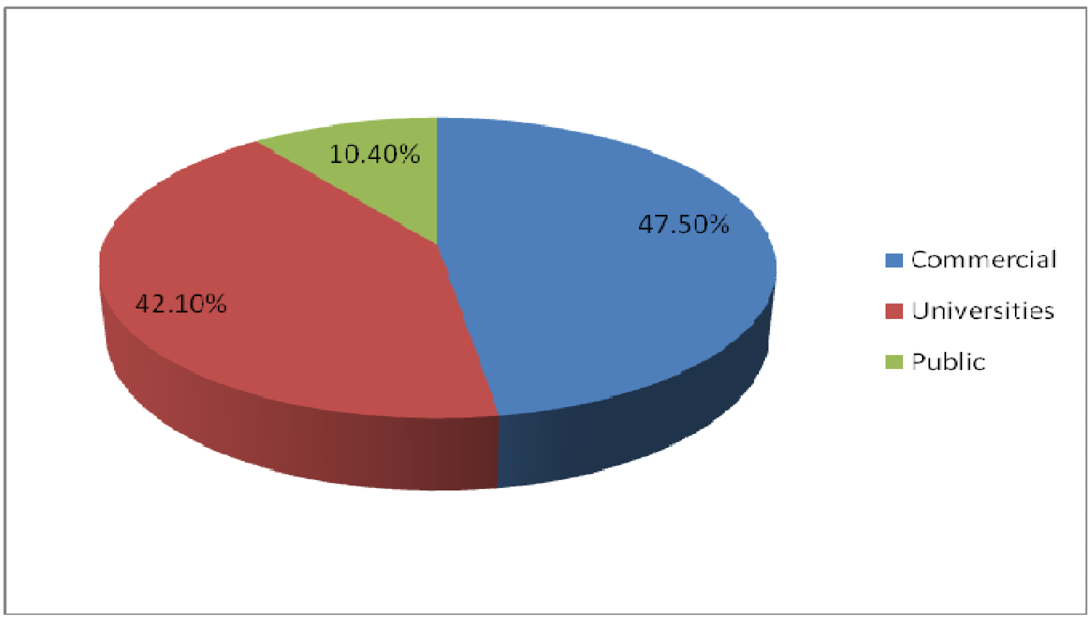

Figure 3A.1. Financing of R&D expenditure in 2013 (%)

When we analyze the distribution of the R&D expenditures according to type, in the same year, more than half of the expenditure has been on personnel (54%) and the lowest expenditure was made on facilities (see Graph 3A.2).

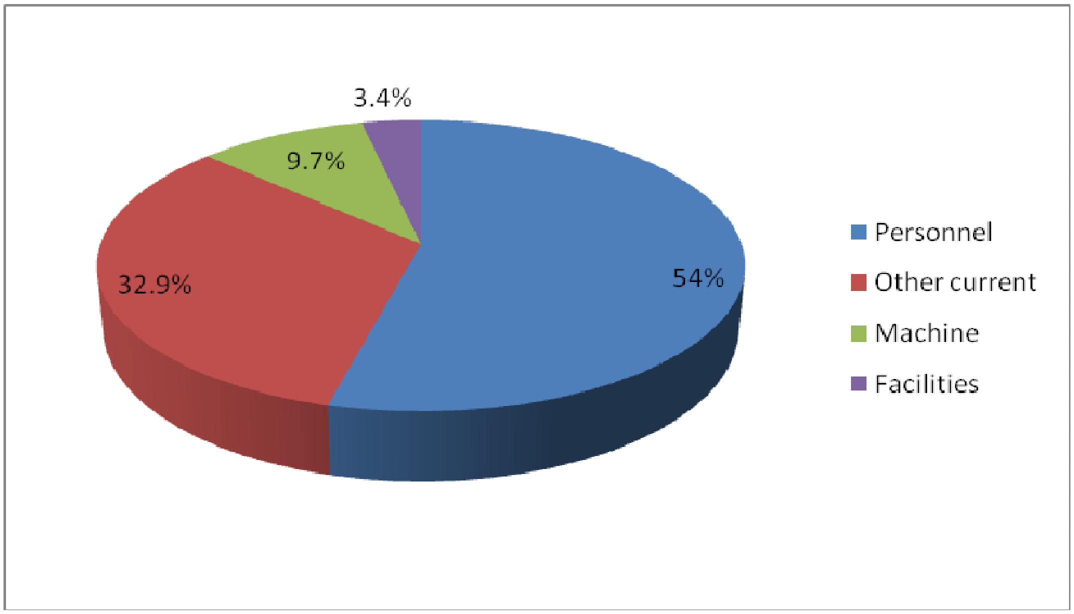

Figure 3A.2. Distribution of R&D Expenditure According to Type in 1993 (%)

Under the 2023 strategy, by 2023 the R&D expenditures is foreseen to reach 60 billion US$ which is 3% of the national income. The supports that are being currently given under the R&D law, Support for Technology Developing Areas, support given by Turkish Scientific and Technological Research Council, supports for SMEs, Small and Medium sized Industry Development and Support (KOSGEB) support for SMEs, Industry Thesis (SANTEZ) program, Credits for Technology Development Projects, Training Support and government incentives for exports.

Appendix 3B. The Sensitivity of Cointegration Results to Structural Changes

In this appendix section we provide the results of the sensitivity analysis on the main cointegration analysis provided in Section 3.5.3 with respect to the various structural changes suggested by Zivot and Andrews (1992) test as well as structural change due to policy change in 1980, i.e. switch from import substitution to export promotion strategy.

The (structural) dummy variables are included as an exogenous variable to the main (benchmark) model in order to account for structural changes.

Table 3B.1. Estimation Results (y_t)

CI Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
k_t	0.3974*	0.5249*	0.3263*	0.3211*	0.3646*	0.3214*
	(0.0758)	(0.1082)	(0.1060)	(0.0962)	(0.0833)	(0.0951)
KNIW	0.5914*	0.4187*	0.6830*	0.6850*	0.7128*	0.7733*
	(0.1418)	(0.1631)	(0.1642)	(0.1582)	(0.1849)	(0.1963)
Constant	4.1910	3.1823	4.7551	4.7992	4.4141	4.7545
Exogenous Variable		DS75	DS79	DS80	DS96	DS80 DS96

Note: (1) The standard errors are provided in brackets. (2) CI (Cointegration) variables are endogenous variables in the cointegration system. The exogenous variable in the vector error correction model controls for the structural change (not included in cointegration vector because it is exogenous). The (structural) dummy variables are included as an exogenous variable to account for structural change. For example, DS75 takes zero until 1975 and it is one for the following years. With the inclusion of structural dummies critical values of cointegration tests are not valid therefore they are not reported in this table. (3) * indicates significance at 5% level.

As can be seen from Table 3B.1 we obtained significant results and the estimates are quite similar to the main results. That is, Model 1 (cointegration results in Section 3.5.3) and the models with structural dummy variables (See Models (2)-(6)) yield qualitatively same results.

Appendix 3C. Sensitivity Analysis on Various Knowledge Pillars

In order to check the robustness of individual indicators of knowledge [sub (dimension) indices] we introduced the knowledge variables (comprising the knowledge index (KNIW)) directly, first one by one and then all together, into the model.

First we introduce the variables one by one into the following model (in spirit of Equation 3.10):

$$y_t = \theta_0^* + \theta_1 ILNKN_i + \theta_3 k_t + u_t \quad \text{(3C.1)}$$

where $ILNKN_i$, i= 1,2,3,4 denote ILNC, ILNO, ILNNP and ILNE, and all variables are defined as earlier.

Equation (3C.1) allows us to investigate whether our results would change if we introduced the four dimensions (indicators) of knowledge on growth separately. For the sake of complete specification we also introduce all four indicators directly into the model as follows:

$$y_t = \theta_0^* + \sum_{i=1}^{4} \varphi_i ILNKN_i + \theta_3 k_t + u_t \quad \text{(3C.2)}$$

where all variables are defined as earlier.

It should be noted again that all knowledge indicators are provided as dimension indices as explained in Section 3.4 so that they are comparable to our main results provided in Section 3.5.3.

To analyse the relationship between these variables and output we have once again used Johansen cointegration analysis as specified in Section 3.3.5. But before estimating cointegration relations we will check for presence of unit root in knowledge variables in the following section.

3C.2.1 Unit Root Tests

Table 3C.1 provides the unit root (DF-GLS)[153] test results.

Table 3C.1. Unit Root (DF-GLS) Tests

Variables	DF-GLS Test		
	Level		First Difference
	Without Trend	With Trend	Without Trend
ILNC	-0.6941 (1)	-1.9801 (1)	-2.1987(0)*
ILNO	-0.6066 (0)	-3.0840 (1)	-5.4431 (0)*
ILNP	0.1519 (0)	-3.1409 (1)	-4.9973 (0)*
ILNE	0.4834 (2)	-1.1739 (0)	-6.1521(0)*

Note: (1) The optimal lag chosen by SBC (Schwarz Bayesian Criterion) are given in parentheses. (2) The maximum lag length is 2. (3) SBC is recommended by ERS (1996) for selecting lag length. (4) The asterisk indicates the rejection of null hypothesis (i.e. the existence of unit root) at the 5% significance level

As is seen from Table 3C.1. for the levels of all the variables, the null hypothesis of a unit root is not rejected but for the first differences of all variables, it is rejected at the 5% significance level. Thus, knowledge indicators contain unit root.

[153] As mentioned previously Elliott-Rothenberg-Stock (ERS) DF-GLS tests (Elliott et al.,1996) are considered to be more powerful than ordinary ADF tests.

3C.2.2 Cointegration Analysis

In this section first we introduce each variable (dimension indices) separately to the model then we estimate our model by introducing all sub indices together to see their joint impact on capital per labor output as set out in Equations 3C.1 and Equation 3C.2, respectively. Cointegration results are provided in Table 3C.2.

Table 3C.2. Estimation Results (y_t)

Variables	Model 1	Model 2	Model 3	Model 4	Model 6
k_t	0.357*	0.1775*	0.6705*	**0.2578***	0.3867*
	(0.0672)	(0.0916)	(0.029)	(0.111)	(0.1197)
ILNC	0.571*				0.3242
	(0.1108)				(0.1807)
ILNO		0.9911*			0.1212
		(0.0916)			(0.0801)
ILNP			0.1098		0.00158
			(0.065)		(0.0421)
ILNE				1.7170*	2.1832*
				(0.200)	(0.3646)
Constant	4.544	5.824	2.1003	9.1591	10.1029
Cointegration	√	√		√	√

Note: The standard errors are provided in brackets and * indicates significance at 5% significance level.

The Trace and Max tests, with the exception of Model 3, suggests one cointegration relation among the variables in all models (see Table 3C.2). As expected, in all models output per labor (y_t) is positively affected by physical capital per labor (k_t). In Model 1, Model 2 and Model 4 knowledge indicators have positive significant effect on output per labor. When we compare their impact on output per labor education has the highest impact followed by openness and communication. On the other hand as can be seen from Table 3C.2 in Model 3 total patents seem to have positive but statistically insignificant effect output per labor. However, when we considered domestic patents instead of total patents we have found significant results. The results of the cointegration analysis with domestic patents is as follows:

$$y_t = 2.412 + \underset{(0.035)}{0.629}\,k_t + \underset{(0.086)}{0.261}\,DP_t \tag{3C.3}$$

where standard errors are presented in brackets, DP is domestic patent (in log and normalized) and the other variables are as defined earlier.

Therefore, these results lend support to our arguments to use various indicators of knowledge as a determinant of TFP and hence growth in Turkey.

In Model 6 we introduce all variables together into the model. All variables seem to have positive effect on output per labor however with the exception of capital per labor and the education sub index the variables are not statistically significant at conventional critical values (see Table 3C.2).

Finally, as can be seen from Model 5 (complete specification) when all four knowledge indicators are introduced to the cointegration analysis only the education variable is found statistically significant. As has been explained in Section 3.3. these indicators are highly correlated and this seems to be causing a serious multicollinearity problem. Thus, the results in this appendix section supports our arguments in favour of constructing a knowledge index to see the impact of knowledge variables on the growth performance of the Turkish economy.[154]

[154] When we re-construct KNIW using domestic patents (DP) rather than total patents we obtained similar results.

Appendix 4A. Share of the Manufacturing Sub-Sectors in the Total Exports (%)

Manufacturing Sub-Sectors	1996	2000	2007	2008	2009	2010
Basic Metal Industry	10.9	8.8	12.2	17.9	15.8	14.7
Motor Vehicles and Trailers	4.8	6.8	16.8	15.3	13.5	14.9
Garments	23.5	21.2	11.7	9.2	10.1	10.4
Textile Products	18.6	18.1	10.7	9.1	10.0	9.6
Machinery and Equipments Not Included in Other Groups	4.0	5.4	7.9	7.8	8.5	8.3
Coke, Refined Petroleum Products and Nuclear Fuels	1.3	1.2	4.9	5.8	3.8	4.2
Foodstuff and Drinks	12.0	7.2	5.1	5.2	6.2	5.8
Metal Commodities (except for machines and equipments)	2.3	2.6	4.2	4.4	4.7	4.5
Electrical Machines and Devices Not Included in Other Groups	3.8	3.2	4.1	4.0	4.3	4.3
Chemicals and Products	6.1	5.5	4.0	4.0	4.5	5.1
Plastic and Rubber Products	2.5	3.1	3.9	3.8	4.2	4.4
Other Non-Metallic Mineral Products	3.8	4.4	3.4	3.5	3.9	3.9
Furniture and Other Products Not Included in Other Groups	1.2	2.5	3.1	2.8	2.9	3.2
Other transportation vehicles	0.8	3.5	2.7	2.7	2.5	1.6
Radio, Television, Communication Equipments and Devices	1.5	3.8	2.7	1.9	2.0	1.9
Paper and Paper Products	0.6	0.6	0.8	0.8	1.0	1.1
Tanned Hide, Bags, Shoes	1.1	0.7	0.6	0.5	0.5	0.6
Tree and Mushroom Products (except for furniture); woven Materials (wicker products)	0.3	0.2	0.5	0.4	0.5	0.5
Medical Products, Sensitive Optic Tools and Clocks	0.3	0.3	0.3	0.3	0.4	0.4
Tobacco Products	0.5	0.5	0.2	0.2	0.3	0.3
Publication, Cassette etc.	0.2	0.2	0.1	0.1	0.2	0.1
Office, accounting and data processing machines	0.1	0.2	0.1	0.1	0.1	0.1

Source : TurkStat

Appendix 4B. The Manufacturing Sub-Sectors in Nace Codes

Table 4A.1 Manufacturing Sub-Sectors in Nace Codes

NACE 1.1 (15-35)	NACE 2 (10-35)
FOOD AND BEVERAGE **15: FOOD PRODUCTS AND BEVERAGES**	**FOOD AND BEVERAGE** **10: FOOD** **11: BEVERAGES**
TOBACCO **16: TOBACCO**	**TOBACCO** **12: TOBACCO**
TEXTILE AND LEATHER PRODUCTS **7: TEXTILE AND TEXTILE PRODUCTS** **18: WEARING APPERAL** **19: LEATHER AND RELATED PRODUCTS**	**TEXTILE AND LEATHER PRODUCTS** **13: TEXTILE** **14: WEARING APPERAL** **15: LEATHER AND RELATED PRODUCTS**
WOOD **20: WOOD**	**WOOD** **16: WOOD**
PAPER PRODUCTS AND PUBLISHING **21: PULP PAPER AND PAPER PRODUCTS** **22: PUBLISHING AND PRINTING**	**PAPER PRODUCTS AND PUBLISHING** **17: PAPER AND PAPER PRODUCTS** **18: PRINTING AND REPRODUCTION OF RECORDED MEDIA**
COKE AND REFINED PETROLEUM PRODUCTS **23: COKE AND REFINED PETROLEUM PRODUCTS**	**COKE AND REFINED PETROLEUM PRODUCTS** **19: COKE AND REFINED PETROLEUM PRODUCTS**
CHEMICALS **24: CHEMICALS AND CHEMICAL PRODUCTS INCLUDING PHARMACEUTICAL PRODUCTS**	**CHEMICALS** **20: CHEMICALS AND CHEMICAL PRODUCTS** **21: PHARMACEUTICAL PRODUCTS**

Table 4A.1 Manufacturing Sub-Sectors in Nace Codes - Continued

RUBBER AND PLASTIC PRODUCTS 25: RUBBER AND PLASTIC PRODUCTS	RUBBER AND PLASTIC PRODUCTS 22: RUBBER AND PLASTIC PRODUCTS
NON-METALIC MINERAL PRODUCTS 26: NON-METALIC MINERAL PRODUCTS	NON-METALIC MINERAL PRODUCTS 23: NON-METALIC MINERAL PRODUCTS
BASIC METALS AND FABRICATED METAL PRODUCTS 27: BASIC METALS 28: FABRICATED METAL PRODUCTS, EXCEPT MACHINERY AND EQUIPMENT	BASIC METALS AND FABRICATED METAL PRODUCTS 24: BASIC METALS 25: FABRICATED METAL PRODUCTS, EXCEPT MACHINERY AND EQUIPMENT
MACHINERY AND EQUIPMENT 29: MACHINERY AND EQUIPMENT n.e.c.(AUTOMATIVE AND AIR SECTOR)	MACHINERY AND EQUIPMENT 28: MACHINERY AND EQUIPMENT n.e.c.
ELECTRICAL 31: ELECTRICAL MACHINERY AND APPARATUS n.e.c. 30: OFFICE MACHINERY AND EQUIPMENT 32: RADIO, TELEVISION AND COMMUNICATION EQUIPMENT AND APPARATUS 33: MEDICAL INSTRUMENTS, WATCHES AND CLOCKS	ELECTRICAL 27: ELECTRICAL EQUIPMENT 26: COMPUTER, ELECTRONIC AND OPTICAL PRODUCTS 32: OTHER MANUFACTURING (Jewelry, bijouterie and related articles; musical equipment, medical and dental instruments

Table 4A.1 Manufacturing Sub-Sectors in Nace Codes - Continued

TRANSPORT **34: MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS** **35: OTHER TRANSPORT EQUIPMENT (SHIPS, TRAMWAY, LOCOMOTIVES, AIRCRAFT, SPACECRAFT, BICYCLES**	**TRANSPORT** **29: MOTOR VEHICLES,TRAILERS AND SEMI-TRAILERS** **30: OTHER TRANSPORT EQUIPMENT** **33: REPAIR OF MACHINERY AND EQUIPMENT**
FURNITURE **36: MANUFACTURING n.e.c. (FURNITURE, CHAIR, KITCHEN, OFFICE ETC.)**	**FURNITURE** **31: MANUFACTURE OF FURNITURE**
RECYCLING **37: RECYCLING**	**RECYCLING** **35: RECYCLING**

Appendix 5. Turkish Summary

Yaşadığımız yüzyılda ülkeler küresel dünya düzeni tarafından şekillenen bir "bilgi ekonomisi"ne doğru yol almaktadır. Bu kapsamda, bilginin çeşitli boyutlarının (sütunlarının), ülke, sektör ve firma düzeyinde, verimlilik ve sermaye birikimi üzerindeki etkisi iktisatçılar ve araştırmacılar tarafından yoğun olarak araştırılmaya başlanan konulardan birisi olmuştur. Bu çalışmaların sonucunda elde edilen bulgulara göre bilgi ekonomisinin farklı boyutları arasında en fazla öne çıkanlar, insan sermayesi, araştırma ve geliştirme (Ar-Ge), bilgi ve iletişim teknolojileri ile uluslararası ticarettir.[155] Bilginin farklı yönlerinin her biri ülkelerin verimlilik düzeyini artırmanın yanı sıra "girdi" birikimini ve dolayısıyla büyüme performansını da etkilemektedirler.

Bu doktora tezinin amacı, hem makro hem de mikro düzeyde bilginin farklı boyutlarının ekonomik büyüme üzerindeki etkilerini incelemektir. Çalışmanın mikro ve makro düzeyde yapılması bize bilginin, büyüme dinamikleri ve yakalama sürecindeki etkisine ilişkin daha kapsamlı bir araştırma yapma olanağı sağlamaktadır. Dolayısıyla bu tez, mikro ve makro düzeyde (ülkelerarası, ulusal ve firma seviyesinde) bilginin bir bütün olarak ekonomik büyüme performansı üzerine etkisini detaylı olarak irdelemeyi hedefleyen üç tane bağımsız makaleden oluşmaktadır.

İlk makale Ekonomik İşbirliği ve Kalkınma Örgütü (OECD) üyesi 34 ülkede, 1995-2011 döneminde, bilginin ekonomik büyüme performansı üzerine doğrudan etkisini incelemenin yanı sıra örgüt içerisinde geriden gelen ülkelerin lider ülkeleri yakalama performansları üzerinde bilginin etkisini de incelemektedir. İkinci makale, dört farklı bilgi göstergesinin, 1960 ile 2010 arasındaki dönemde,

[155] Daha fazla detay Griliches (1962, 1992, 1994), Romer (1986), Lucas (1988), Grossman ve Helpman (1994), Benhabib ve Spiegel (1994), Nelson ve Phelps (1966) ve Chen ve Dahlman (2004) makalelerinde bulunabilir.

Türkiye'nin ekonomik büyüme performansına olası etkisini incelemektedir. Üçüncü makale ise 2003'den 2010'a kadar olan dönemde, Türkiye imalat sektöründeki firmaların, kendi Ar-Ge'leri ile sektördeki mevcut bilginin yayılımının firmaların verimlilik düzeylerine etkisini araştırmaktadır.

Aşağıda, bu doktora tezini oluşturan ve yukarıda bahsi geçen üç makalenin geniş özeti sırasıyla sunulacaktır.

1. Makale: Bilgi, Teknolojiyi Yakalama ve Ekonomik Büyüme: OECD Ülkelerini Kapsayan bir Panel Veri Analizi

Nobel ödüllü Robert M. Solow başta olmak üzere, bazı ekonomistler, arkadan gelen fakir ülkelerin mevcut teknolojik yeniliklere veya gelişmelere hiçbir engelle karşılaşmadan rahat bir şekilde erişim sağlayabileceğini ve bunun neticesinde uzun dönemde fakir ülkelerin zengin ülkelerin gelir düzeyini yakalayacaklarını (yakınsayacaklarını) savunmaktaydılar. Daha sonraki dönemlerde araştırmacılar arkadan gelen ülkelerin mevcut teknolojik yenilikleri rahat bir şekilde kullanabilmelerinin ancak benzer teknolojik altyapıya sahip olmaları durumunda gerçekleşebileceğini vurgulamışlardır. Bu akımın adı "teknoloji açığı"dır. Teknoloji açığı teorisyenleri, teknolojik farkların ülkelerin gelir düzeyleri arasındaki farkın ana nedeni olduğunu ve geriden gelen ülkelerin lider ülkelerin gelir seviyelerine ulaşmak için teknoloji bakımından onları yakalamaya çalıştıklarının altını çizmektedirler. Buradaki can alıcı argüman, özellikle çok geriden gelen ülkelerin lider ülkeleri yakalamalarının neredeyse imkansız olmasıdır. Çünkü gerideki ülkeler mevcut teknolojiyi kullanmak için gerekli kapasiteye sahip olana kadar, lider ülkeler ileri düzeydeki araştırma ve geliştirme (Ar-Ge) altyapılarıyla yeni teknolojiler geliştirerek daha yeni ve üst düzey teknoloji sınırına doğru ilerlemektedirler. Dolayısıyla, dünyada birkaç istisnai ülke dışında (genelde bunlar lider ülkelerin teknolojik yapılarına yakın olan ülkelerdir), ülkelerin lidere yakınsamalarından ziyade, zengin ve fakir ülkeler arasındaki teknoloji ve gelir farkı sürekli artmaktadır.

Bu alanda önde gelen çalışmalardan birisi Nelson ve Phelps (1966) tarafından yapılmıştır. Nelson ve Phelps (1966) makalelerinde eğitimi yeni teknolojileri kullanma ve anlama becerisini şekillendiren en önemli faktör olarak sunmuşlardır. Eğitimin önemini vurgulamak için makalelerinde çiftçi örneğini kullanmışlardır. Bu örnekte ancak yeterli düzeyde teknik bilgiye sahip olan çiftçinin, piyasaya sunulan yeniliklerin getireceği olası avantajı daha iyi öngörebileceği ve bunu ilk kullanan olarak rakipleri karşısında daha fazla rekabet gücüne sahip olacağı belirtilmektedir. Diğer bir deyişle, Nelson ve Phelps (1966) yeni teknolojileri ancak bu teknolojiyi anlamak ve kullanabilmek için belirli bilgi birikimine (hem yazılı hem de zımni) sahip olanların avantajlarına çevirebileceklerini vurgulamaktadırlar.

Benzer şekilde ülkelerin bilgi birikimleri de teknoloji açısından lider olan ülkeleri yakalamalarında belirleyici rol oynamaktadır. Dolayısıyla bilgininin mevcudiyetinden ziyade bu bilgiyi anlayabilecek ve kullanabilecek kalite seviyesi (bilgi birikimi) ülkeler arasındaki yakalama ve yakınsama sürecinde belirleyici olmaktadır.

Benhabib ve Spiegel (1994) çalışmalarında, Nelson ve Phelps'in yaklaşımını temel alarak, yeni büyüme teorilerinin endojen yapısını kullanıp beşeri sermayenin, 60 ülkenin 1965'den 1985'ye kadar olan dönemde, ekonomik büyüme ve yakınsama süreçleri üzerine etkisini incelemişler.

Benhabib ve Spiegel (1994) ilk geliştirdikleri modelde beşeri sermayenin kişi başına GSYH üzerinde doğrudan etkisinin olmadığını ancak beşeri sermaye stokunun toplam faktör verimliliğinin büyüme hızını belirlediğini göstermişlerdir. Kısacası, eğitim kalitesinin ülkelerin toplam faktör verimliliğini etkilediğini tespit etmişlerdir.

Makalelerinde oluşturdukları modelde Benhabib ve Spiegel (1994), lider ülke ile arkadan gelen ülkeler arasındaki teknolojik açığını, arkadan gelen ülkenin eğitim seviyesinin belirlediğini savunmaktadırlar. Diğer bir deyişle, beşeri sermayenin ülkelerin teknoloji kabiliyetlerinin üzerinde iki rolünün olduğunu belirtmektedirler. Birincisi, beşeri sermaye ülkenin teknoloji yenilikleri (inovasyonu) konusundaki yerel kabiliyetini belirlemekte ve ikinci olarak ithal edilen teknolojinin adaptasyonu ve kullanımında belirleyici olmaktadır.

Modelde, lider ülke en yüksek toplam faktör verimliliğine sahip olan ülke olarak tanımlanmaktadır. Daha sonra arkadan gelen bir diğer ülke lider ülkenin eğitim düzeyini geçtiği zaman, lider ülke eğitim avantajını kaybetmekte ve dolayısıyla arkadan gelen bu ülke lider ülke konumuna yükselmektedir. Ayrıca, Benhabib ve Spiegel (1994) toplam faktör verimliliği bakımından lider ülkeye uzak (daha düşük toplam faktör verimliliğine sahip) olan ülkelerin, yakınsama etkisi nedeniyle, daha yüksek düzeyde büyüme oranına sahip olacaklarını varsaymaktadır. Bununla bağlantılı olarak lidere hem eğitim hem de teknoloji bakımından çok yakın olan ülkelerin büyüme oranlarının hem daha düşük olacağı hem de bu durumda yakalama etkisinin de anlamsız olacağıdır.

Tezin ilk makalesinde oluşturulan model, Benhabib ve Spiegel (1994) çalışmasını temel alarak, bilginin ülkelerin uzun dönemdeki büyüme performansı ve yakalama (yakınsama) süreçlerine etkisinin olup olmadığını incelemeyi hedeflemektedir.

Makalede ilk olarak, Benhabib ve Spiegel’den (1994) farklı olan nokta, beşeri sermayenin yanı sıra AR-GE, uluslararası ticaret ve bilişim teknolojileri gibi bilginin önde gelen diğer boyutlarını da modele eklenerek bilginin daha kapsamlı olarak ülkelerin yakalama sürecindeki etkisi incelenmeye çalışılmıştır. Daha sonra, Griliches (1980) gibi Ar-Ge harcamalarının GSYH’ya oranını Ar-Ge göstergesi olarak kullanmak yerine (bilgi birikiminin mevcut ve geçmiş Ar-Ge harcamalarının fonksiyonu olduğunu göz önünde bulundurarak) makalede Ar-Ge stoku sürekli envanter sistemi metoduna uygun olarak hesaplanıp kullanılmıştır. Daha sonra ilk modeli 34 OECD ülkesinin 1995'den 2011'i kapsayan dönem için panel veri ile bilginin ekonomik büyüme ve üye ülkelerin lider ülkelere yakınsaması incelenmeye çalışılmıştır. Bu analizin sonucunda elde edilen ampirik sonuçların çoğunluğu teorik ve istatistiksel olarak beklenen sonuçları vermemiştir. Bu sonuçların nedenlerini araştırdığımızda Nelson ve Phelps'in (1966) spesifikasyonunu takip eden Benhabib ve Spiegel (1994) modelinin yapısında ciddi kısıtlamalar olduğu tespit edilmiştir. Daha önce belirtildiği gibi Nelson ve Phelps (1966) yeni teknolojilerin kullanımında veya adaptasyonunda eğitimin diğer bir deyişle beşeri sermayenin kalitesinin belirleyici olduğunun altını çizilmektedir. Dolayısıyla Nelson ve Phelps (1966) beşeri sermayeyi modele toplam faktör verimliliği üzerinden eklemekte ve aynı şekilde onları takip eden Benhabib ve Spiegel (1994) ve dolayısıyla ilk başta bizde Nelson ve Phelps'in spesifikasyonunu takip ederek bilgi göstergelerini (beşeri sermaye ve AR-GE stoku dahil) modele yalnızca toplam faktör verimliliğinden dahil ettiğimizden dolayı sorunla karşılaştığımızı tespit ettik.

Yeni modelimize, Lucas'ı (1988) takip ederek, beşeri sermayeyi fiziki sermaye gibi modele bir girdi olarak dahil ettiğimizde, büyüme sürecinde beşeri sermaye birikiminin rolünü yakalamakta daha başarılı sonuçlara ulaşılabileceği bulunmuştur. Dolayısıyla, makalenin ikinci kısmında, Lucas'ı (1988) takip ederek beşeri sermaye fiziki sermayenin yanı sıra ilave girdi olarak ve diğer bilgi değişkenlerini (uluslararası ticaret, Ar-Ge ve bilişim teknolojilerini) ise Griliches (1979) ve Eberhardt ve ark. (2013) takip ederek değişim faktörleri olarak modele eklenmiş ve bu yeni üretim fonksiyonu genişletilmiş bilgi üretim fonksiyonu olarak adlandırılmıştır.

Ayrıca, makalenin ilk kısmında Benhabib ve Spiegel'i (1994) takip ederek uyguladığımız statik panel veri analizi yerine ikinci modelin analizinde dinamik panel veri analiz tekniği kullanılmıştır. Bu yeni yaklaşım, modeldeki uzun dönem ilişkisini dikkate alarak, verideki bilginin uzun dönemli etkisini gözlemleme imkanı sunmuştur. Bu bir önceki analizde, Benhabib ve Spiegel (1994) yaklaşımında üretim fonksiyonunun fark (difference) formunda olması nedeniyle değerli uzun dönem bilgileri kaybedildiğinden dolayı mümkün olmamaktaydı. Bu nedenle Peseran ve ark. (1999) çalışmasını takip ederek sadece uzun dönemli katsayılarının tüm ülkeler için aynı olduğu ve ülkeler arasında kısa dönemli katsayıların farlılık gösterdiği Birleşik Ağırlıklı Grup (BAG) tahmin metodunu kullanmaya karar verdik. Yeni üretim fonksiyonunun BAG tahmin sonuçlarını hem teorik hem de istatistiksel olarak anlamlı bulduk. Diğer bir deyişle, bu yeni yöntemle 1995-2011 döneminde 34 OECD ülkesini kapsayan analizimiz, bilgi (beşeri sermaye, bilişim teknolojileri, Ar-Ge ve uluslararası ticaret) değişkenlerinin bir bütün olarak hem OECD üyelerinin ekonomik büyüme performansları üzerinde olumlu etkisi olduğu hem de geride kalmış OECD ülkelerinin uzun dönem ortak bir dengeye yakınsadığı sonucuna ulaşılmıştır.

Özetle, birinci makalenin ilk önemli bulgusu, Benhabib ve Spiegel (1994) modeli ve bu makaleyi takiben kullanılan ampirik yaklaşımların ciddi zafiyetlerinin olduğunu belirlemek olmuştur. Bu sonuç doğrultusunda, araştırmanın ileriki aşamalarında bilginin ekonomik büyüme üzerine etkisini inceleyebileceğimiz yeni bir alternatif model oluşturmaya ve bu modeli yeni bir ampirik metodoloji ile incelemeye çalıştık. Neticede oluşturduğumuz yeni yaklaşım, OECD ülkelerinde teorik olarak beklediğimiz gibi bilginin ekonomik büyüme üzerinde etkisinin olduğunu ve bilgi göstergelerinin ülkelerin uzun dönemde ortak büyüme dengesine yakınsamalarında etkili olduğunu göstermiştir. Sonuç olarak, bu makale hem bilginin ülkelerin büyüme ve yakınsama performansları üzerinde etkili olduğunu hem de literatürde önde gelen bazı çalışmaların da ciddi zayıflıklarının olabileceğini göstermiştir.

2. Makale: Bilginin Ekonomik Büyümedeki Rolü: Türkiye Örneği, 1963-2010

Üçüncü bölümde sunulan ikinci makalede, üretim fonksiyonu yaklaşımı ve zaman serisi teknikleri kullanılarak, 1963-2010 döneminde, bilginin bir bütün olarak

Türkiye’nin ekonomik büyüme performansı üzerindeki etkisi incelenmeye çalışılmıştır.

Bir önceki makalede olduğu gibi bilginin dört farklı boyutu olan beşeri sermaye, Ar-Ge, uluslararası ticaret ve bilişim teknolojileri kullanılmıştır.

Bu makalenin iki tane önemli katkısı bulunmaktadır. İlk olarak, bildiğimiz kadarıyla, bilginin Türkiye’nin ekonomik performansı üzerine yapılan daha önceki çalışmalarda, bilginin farklı boyutları bir arada araştırılmadığı ve genelde sadece bilginin tek bir boyutu, özelikle Ar-Ge, araştırmalarda incelenmiştir. Örneğin, Kar ve Ağır (2004), Özsoy (2009) ile Şimşek ve Kadılar (2010) sadece Ar-Ge’nin farklı boyutlarının Türkiye’nin ekonomik büyüme performansı üzerine etkisini incelemişlerdir. Dolayısıyla, bu makalenin ilk katkısı Türkiye'nin ekonomik büyüme performansı üzerinde bilginin dört farklı boyutunun (göstergelerinin) etkisinin bir bütün olarak incelenmiş olmasıdır. Bu kapsamda, önce içsel büyüme modellerinin farklı yapılarını dikkate alarak bilginin farklı boyutlarını (örneğin, insan kaynakları, Ar-Ge, ticaret, vs.) Türkiye’nin ekonomik büyüme sürecindeki etkisini inceleyebileceğimiz yeni bir model geliştirdik.

Makalenin ikinci katkısı ise bilginin bir bütün olarak Türkiye ekonomisine etkisini daha iyi bir şekilde yakalayacağını düşünerek oluşturduğumuz “bilgi endeksi”dir. Diğer bir deyişle, bilgi endeksi bilginin farklı boyutlarının bir bütün olarak tek veri halinde ve daha kapsamlı olarak bilginin ekonomideki düzeyini ölçmemize olanak tanımaktadır. Ayrıca, bilgi endeksinin oluşturulması bize sadece ekonomideki bilgi düzeyinin bir bütün olarak kapsamlı bir ölçümünü vermekle kalmayıp aynı zamanda bilgi değişkenleri arasındaki olası çoklu doğrusallık problemini de gidermemize olanak tanımaktadır.

Makalede bilgi sütunlarının (boyutlarının) göstergeleri olarak; ortalama eğitim süresi beşeri sermayenin göstergesi; toplam telefon abone sayısı bilişim teknolojilerinin göstergesi; toplam uluslararası ticaretin (ithalat artı ihracat) Gayri Safi Yurtiçi Hasılaya (GSYH) oranı uluslararası ticaretin göstergesi; ve son olarak toplam patent başvuruları da Ar-Ge göstergesi olarak kullanılmıştır. Bilgi sütunlarının göstergelerinin seçiminde hali hazırda kullanabileceğimiz mevcut veriler belirleyici olmuştur.

Bilginin dört boyutunun farklı değerlere ve farklı üst ve alt sınır (minimum ve maksimum) değerlerine sahip olmasından dolayı endeksi oluştururken İnsani Gelişme Endeksinin metodolojisinden faydalandık. Bu yöntem kapsamında, ilk önce makalede incelediğimiz bilginin her bir sütunun göstergesinin minimum ve maksimum sınırlarını belirledik ve bu değerler kapsamında her bir gösterge için sıfır ile bir arasında endeks değeri belirlendi. Bu değişimin ardından ilk başta farklı birimlerden oluşan dört bilgi göstergesinin değerlerini birimden arındırılmış, sıfır ve bir arasında olan, ham verilere dönüştürerek hem kıyaslanabilmelerine hem de onları bir arada kullanma olanağına kavuşmuş olduk. Daha sonra söz konusu dört farklı bilgi göstergesinden tek bir gösterge (bilgi endeksi) oluşturabilmek için her bir bilgi göstergesi için ayrı ayrı (alt) boyut endeksi hesaplanmıştır.

Bilgi göstergelerini normalleştirdikten ve her bir göstergenin ayrı ayrı boyut endeksini hesapladıktan sonra Bilgi Endeksini dört alt endeksin ortalama ağırlığı olarak hesapladık.

Birleşmiş Milletler tarafından geliştirilen İnsani Gelişme Endeksinde her alt endeksin ağırlığı belirlenirken basit ortalama ağırlık metodolojisi kullanılmaktadır. Bunun nedeni bu endekste kullanılan üç boyutun eşit oranda ağırlığa sahip olduğunun varsayılmasıdır. Ancak, biz basit ortalama ağırlık metodolojisini kullanmak yerine, Alesina ve Perotti (1996) ile onun benzeri olan çalışmaları göz önünde bulundurarak, temel bileşen analizini kullanarak her göstergenin ilgili ağırlığını belirlemeye çalıştık. Daha sonra temel bileşen analizinin sonucunda elde ettiğimiz ağırlıkları kullanarak Bilgi Endeksini hesapladık.

Kısacası makalede içsel büyüme teorisinden faydalanarak oluşturduğumuz modelimizden sonra bilginin bir bütün olarak Türkiye ekonomisinin üzerindeki olası etkisini incelemek için bilgi endeksi oluşturduk. Bu bilgi endeksi bilginin dört farklı boyutunu kapsayan dört alt endeksin birleşiminden oluşmaktadır. Dolayısıyla, bu bilgi endeksi bize belirli bir zaman diliminde bilginin düzeyini göstermektedir. Diğer bir deyişle, bilgi endeksi bize Türkiye'nin bilgi düzeyindeki gelişimi analiz etme imkanı sağlamaktadır. Örneğin, eğer Türkiye'de bir önceki yıla kıyasla mevcut bilgi endeksi daha yüksek seviyede ise bu bize bilgi düzeyinde bir iyileşme veya gelişme olduğunu göstermektedir. Ancak, bilginin boyutlarını (sütunlarının) değerlendirirken, özellikle uluslararası ticaret ve Ar-Ge'nin, ekonomik şartlara (örneğin ekonomik kriz) karşı çok hassas olduğunu göz önünde bulundurmak ve buna göre sonuçları değerlendirmek gerekmektedir.

Hesaplamış olduğumuz bilgi endeksi bize 1963-2010 döneminde Türkiye'deki bilgi düzeyinde sürekli bir artışın gerçekleşmiş olduğunu göstermektedir.

Zaman serisi (eşbütünleşme) analizinin sonucu bilginin farklı sütunlarının bir bütün olarak söz konusu dönemde (1963-2010) Türkiye'nin ekonomik büyüme oranı üzerinde hem pozitif hem de istatistiksel olarak anlamlı etkisi olduğunu göstermiştir. Diğer bir deyişle, makalemizde incelediğimiz bilginin dört farklı boyutu bir bütün olarak 1963-2010 döneminde ülkemizin ekonomik büyüme performansına olumlu katkı sağlamıştır.

3. Makale: Bilginin Firmaların Verimliliği Üzerine Etkisi: Türkiye İmalat Sanayi üzerine bir Mikro Ekonomik Analiz

Tezin dördüncü bölümünde yer alan üçüncü makalede bilginin Türkiye imalat sanayi üzerindeki etkisi firma düzeyinde panel veri ve genelleştirilmiş momentler metodu (GMM) kullanarak 2003'den 2010'u kapsayan dönem için analiz edilmiştir.

Firmaların varoluşlarını belirleyen en önemli etkenlerden birisi olmasından dolayı, firma düzeyinde yapılan birçok çalışmada verimliliğin firmaların büyüme düzeyi üzerindeki etkisine yoğunlaşılmaktadır.

Firmaların verimliliğine katkı sağlayan faktörler ikiye ayrılmaktadır. Bunlar içsel (firma büyüklüğü, insan kaynakları, Ar-Ge yatırımları, vs.) faktörler ve dışsal (endüstriye özel karakteristikler, örneğin işçi hareketi, kurumsal altyapı) faktörlerdir. Genelde firmaların verimliliği bu iki faktörün alt bileşenlerinin birleşiminden oluşmaktadır. Örneğin, Griliches (1992, 1994), insan sermayesi, ölçek ekonomileri ve endüstriye özel faktörlerin firmaların verimlilik düzeyini belirleyen temel faktörler olduğunu belirtmektedir.

Yakınsama (yakalama) bakımından firma düzeyindeki argümanlar makro düzeydeki (birinci makalede bahsi geçen) argümanlarla örtüşmektedir. Bir tarafta, lider firmadan yeni bilginin takipçi firmalara olacak yayılımının eninde sonunda tüm firmaların büyüme oranlarını yakınlaştıracağına ilişkin argümanlar yer alırken diğer tarafta lider firmaya sadece teknik bilgi ve yetenek bakımından yakın olan firmaların, daha geriden takip eden diğer firmalara kıyasla, daha hızlı bir şekilde aynı düzeyde verimlilik seviyesini yakalayacağını belirtilmektedir. Findlay (1978) lider firma ile takip eden firmaların arasındaki teknolojik fark ne kadar fazla olursa yakınsama mesafesinin de fazla olacağını ve dolayısıyla arkadan gelen firmaların Ar-Ge'lerindeki gelişmenin de daha hızlı olacağını belirtmektedir. Diğer yandan Cohen ve Levinthal (1990) lider firma ile benzer teknolojik altyapıya sahip geriden gelen firmaların diğerlerine kıyasla daha hızlı bir şekilde lider firmanın verimlilik oranına yakınsayacağını belirtmektedirler. Başka bir deyişle hem firmaların arasındaki mesafe hem de kabiliyetlerinin heterojenlik düzeyi geriden gelen firmaların lider firmayı yakalama hızını belirmektedir.

İkinci makalede olduğu gibi, birkaç çalışma dışında, Türkiye'de firma düzeyinde bilginin verimlilik üzerine etkisini araştıran çalışmalarda sadece Ar-Ge'nin farklı yönleri araştırılmıştır. Hiç kuşkusuz bu çalışmalar bize firmaların verimlilik düzeylerinde etkili olan faktörlere ilişkin değerli ve faydalı bilgiler sağlamaktadır.

Bildiğimiz kadarıyla, Türkiye imalat sanayindeki firmalara ilişkin olarak hem bilginin firmaların performanslarının üzerindeki farklı boyutları hem de bilginin farklı göstergelerinin geriden gelen firmaların yakınsamaları üzerindeki etkisi en kapsamlı olarak yakın zamanda Ülkü ve Pamukçu (2015) tarafından incelenmiştir.

Ülkü ve Pamukçu (2015) Türkiye'de 2003'den 2007'ye kadar olan dönemde imalat sanayindeki firmaların verimliliği üzerine Ar-Ge'nin etkilerini ve bilginin difüzyonunun (yayılımının) Türkiye İstatistik Kurumunun (TÜİK) Sanayi ve Hizmetler anket verilerini kullanarak incelemişlerdir. Bu çalışmanın sonuçları, Ar-Ge yoğunluğunun artmasının eşik düzeyde teknik kapasiteye sahip firmaların verimlilik düzeyini arttırdığını göstermiştir. Daha önce belirtildiği gibi, bu çalışmayı bilgi göstergelerinin Türkiye imalat sanayindeki firmaların verimliliği üzerini etkisini araştıran en kapsamlı çalışma olmasından dolayı temel almaya karar verdik. Bu karar doğrultusunda, Ülkü ve Pamukçunun (2015) analizini TÜİK'in üç farklı anketinin verilerini kullanarak oluşturacağımız daha kapsamlı bir veri seti ve daha uzun zaman boyutu ile güncellemeyi hedefledik.

Ülkü ve Pamukçu (2015) çalışmalarında daha önce değinildiği gibi sadece TÜİK'in Sanayi ve Hizmetler anket verilerini kullanmışlardı. Bizim ilk farkımız TÜİK'in üç farklı anketini, diğer bir değişle Sanayi ve Hizmetler anketi, Ar-Ge anketi ve Dış ticaret Anketi verilerini kullanarak yeni bir veri seti oluşturmak oldu. Bu yeni veri setinin en önemli özelliği Ar-Ge anketinde yer alan Ar-Ge verilerinin Frascati Kılavuzuna uygun olarak derlenmiş olan verilerden oluşmasıdır. Ayrıca, daha uzun zaman boyutunda verilerin mevcut olmasından dolayı bizim çalışmamız daha uzun bir zaman sürecini (2003-2010) kapsamaktadır.

Ampirik sonuçlarımız Ülkü ve Pamukçu'nun (2015) fiziki sermaye stoku, firma içi Ar-Ge stoku, pazar konsantrasyonu, uluslararası ticaret, teknolojik kapasite ve yabancı sermayenin Türkiye imalat sanayindeki Ar-Ge aktivitelerinde belirleyici olduğu konusundaki bulguları desteklemektedir. Sonuçlarımız teknolojik kapasitenin firmaların sanayideki mevcut Ar-Ge kullanma becerisinin belirleyicilerinden biri olduğunu göstermektedir. Ülkü ve Pamukçu (2015) ile bizim ampirik sonuçlarımız arasındaki en önemli fark, hem tüm hem de yerel örneklemde, Ar-Ge dışsallığı (yayılması) ve yabancı firmaların Ar-Ge dışsallığının verimlilik üzerinde her üç (minimum, maksimum ve ortalama) düzeyinde etkisinin olmamasıdır. Sonuçlarımız, Türkiye imalat sanayinde Ar-Ge yatırımları açısından ciddi sorunlar olduğunun bir göstergesidir. Daha önce değindiğimiz gibi, bizim veri setimizde zaman boyutu 2010'a kadar uzatılmıştır. Dolayısıyla bizim sonuçlarımız, 2008 yılında yaşanan küresel finansal krizinin ve artan uluslararası rekabetin Türk imalat sektöründeki firmaların Ar-Ge yatırımlarının üzerinde olumsuz etkisinin olduğunu göstermektedir. Diğer bir deyişle, krizden ve artan rekabet ortamından dolayı Ülkü ve Pamukçu'nun (2015) çalışmasını takip eden 2008-2010 döneminde Ar-Ge yatırımlarını belirleyen bu faktörlerin önemlerinin azaldığı görülmektedir.

Sonuç olarak, tezde yer alan üç makale bilginin –verimlilik ve/veya sermaye birikimi aracılığıyla– büyüme üzerine etkisini makro ve mikro düzeyde (uluslararası, ulusal ve sektörel düzeyde) incelemektedir. Özellikle, en önemli bilgi sütunlarının (beşeri sermaye, Ar-Ge, uluslararası ticaret ve bilişim teknolojileri), geriden gelen ülkelerin yakalama (yakınsama) çabaları (Makale 1); Türkiye'nin genel ekonomik büyüme performansı (Makale 2) ve Türkiye imalat sektöründeki firmaların verimliliği üzerine etkisini (Makale 3) incelemektedir.

POLİTİKA ÖNERİLERİ

Daha önce belirtildiği gibi, bu tezin amacı bilginin farklı sütunlarının verimlilik ve ekonomik büyüme üzerindeki etkilerinin araştırılmasıdır. Tezde yer alan üç makalenin sonuçları bilgi göstergelerinin ekonomik büyüme performansları üzerinde hem makro hem de mikro düzeyde katkısı olduğunu göstermiştir. Bu kısım, politika önerilerimizi makro, mezo ve mikro düzeyde sunmayı amaçlamaktadır.

Ancak, her ne kadar politika önerilerimizi makro, mezo ve mikro düzeylerde sunmaya çalışsak da, bazen bu üç düzeyin arasındaki çizgilerin çok bulanık olabileceğini ve bir düzeyde belirtilen önerinin kolayca diğer düzeyde de uygulanabileceğinin altını çizmek önemlidir.

Makro Düzeyde Öneriler

Bu tez kapsamında incelenen bilginin farklı sütunları ve onların ekonomik büyüme üzerine olası sonuçları hakkında elde edilen sonuçlar kapsamında makro (ulusal) düzeydeki politika önerilerimize aşağıda yer verilmektedir.

- ***Ülkelerin ihtiyaçlarına uygun özel politikalar:*** Sonuçlarımız bilgi sütunlarının (değişkenlerinin) ülkelerin ekonomik büyüme süreçleri üzerinde olumlu etkisinin olduğunu ve bu nedenle ülkelerin gelişimi açısından önemli olduğunu gösteriyor. Ancak, büyüme performanslarını arttırma sürecinde ülkelerin mevcut bilgi sütunlarını kullanma (veya faydalanma) yeteneklerinde önemli düzeyde farklılık gözlenmektedir. Tezde yer alan birinci makalenin sonuçlarından da görüldüğü üzere, ülkelerin yapıları homojen değildir ve bu bize ülkelerin sosyal ve ekonomik yapılarındaki farklılıkların belirleyici olduğunu göstermektedir. Ülkelerin heterojen yapıları, halihazırda mevcut olan bilgiyi verimli olarak kullanabilmelerini ve dolayısıyla lider ülkeleri yakalama kabiliyetlerini belirlemektedir. Ayrıca bu heterojen yapıdan dolayı, ülkeler kolay yolu tercih ederek başka bir ülkenin başarılı sonuçlar aldığı politikayı uyguladıkları zaman (özellikle söz konusu ülkelerin sosyo-ekonomik yapıları arasında farklılık olması durumunda) olumlu sonuç almaları çok düşük bir ihtimaldir. Bu nedenle, ülkeler mevcut yapılarını dikkatlice analiz etmeli ve bunun sonucunda kendi özel ihtiyaçlarına yönelik oluşturulacak özel politikalar ile daha başarılı sonuçlara ulaşılabilineceği hususu göz zrdı edilmemelidir.

Bu tezdeki çalışmaların sonucunda elde ettiğimiz önemli bulgulardan bir diğeri arkadan gelen ülkelerin (veya firmaların) bilgi birikimi bakımından lider ülkelerden (veya firmalardan) çok geride olmaları durumunda lider ülkeyi yakalamalarının zorlaştığı ve neredeyse imkansızlaştığıdır. Diğer bir deyişle, uzun dönemde arkadan gelen ülkeler, lider ülkeleri ancak benzeri bir alt yapıya (örneğin, ekonomik, kurumsal yapı, insan kaynakları vs.) sahip olmaları durumunda yakalayabiliyorlar ve tüm bunlar aynı zamanda söz konusu ülkenin sosyal ve özümseme yeteneğini belirlemektedir. Dolayısıyla yakalama süreci benzeri sosyal ve özümseme yeteneğine sahip ülkeler/firmalar arasında daha kolay bir şekilde gerçekleşmektedir.

Bu nedenle, politika yapıcılar, ülkelerin yetenekleri arasındaki heterojenitenin söz konusu ülkenin ihtiyaçlarını hedefleyen özel politikalar gerektirdiğinin ve tüm ülkelerde uygulanabilecek standart bir politika olmadığının farkında olmalıdırlar. Bu husus özellikle, kısıtlı kaynaklara sahip olan ve bu kaynakları deneme yoluyla harcama lüksüne sahip olmayan gelişmekte olan ülkeler açısından büyük önem taşımaktadır. Dolayısıyla, en ileri düzeydeki teknolojileri üretmeyi hedeflemek yerine takip eden ülkeler, mevcut alt yapılarını ve yeteneklerini göz önünde bulundurarak, başarılı olabilecekleri ve ülkenin gelişiminde getirisi daha yüksek olabilecek teknolojileri adapte etmeye çalışmalıdırlar.

Özetle, politika yapıcıların ilk yapması gereken ülkenin veya hedeflenen sektörün (endüstrinin) mevcut durumunu (yeteneklerini) detaylı olarak analiz etmelidirler. Politika yapıcılar mevcut durumun analizini yaparken, işgücünün kalitesini, mevcut altyapıyı, kamu kurumlarında teknoloji kullanımı ve yayılımını sağlama yeteneklerinin analizine önem vermelidir. Politika yapıcılar, ülkenin teknoloji kabiliyetleri konusunda kapsamlı ve ayrıntılı analize sahip olduktan sonra ülkenin özel ihtiyaçlarını hedef alarak mevcut kaynakları etkin bir şekilde kullanabilme olanağına ve hangi tür teknolojinin ülkenin uzun veya kısa dönem büyüme sürecinde etkili olacağını belirleyebileceklerdir. Bunun yanı sıra, uzun vadede ekonomik büyüme hedefine ulaşılması için oluşturulan ve uygulanan politikaların sürekli gözden geçirilmesi ve gerekli durumlarda değişiklik yapılarak güncellenmeleri gerekmektedir.

- ***<u>Veri kalitesi:</u>*** Tezde yer alan her üç makalede de yaşanan ortak ve en önemli kısıt verinin mevcudiyeti ve kalitesine ilişkin sorundu. Örneğin, birinci makalede bilginin ülkelerin ekonomik büyüme üzerine etkileri ve lider ülkeleri yakınsama süreçlerini incelerken, analizi sadece OECD ülkeleri ile sınırlandırmamızın temel sebebi birçok ülkenin mevcut olan bilgi göstergelerine ilişkin güvenilir ve kıyaslanabilir verilere sahip olmamasına ilişkin sorunla karşılaşılmasıydı. Ancak, her ne kadar OECD ülkelerinin birçoğunun bilgi göstergelerine ilişkin verileri mevcut olsa da özellikle OECD'ye yeni katılan eski Sovyet Birliği ülkelerinin veri eksikliği olmuştur. İkinci makalede ise, Türkiye'nin 1963'den 2010'a kadar Ar-Ge harcamalarına ilişkin tam (eksiksiz) veri bulunmadığından patent verileri Ar-Ge göstergesi olarak kullanılmak zorunda kalınmıştır. En son makalede ise kullandığımız üç TÜİK anketinde firmaların bilgi teknolojileri harcamaları konusunda somut veri yer almadığından bu gösterge yerine firmaların yazılım harcamaları kullanılmıştır.

Gerçekçi ve güvenilir politikalar oluşturulabilinmesi için ihtiyaç duyulan verilerin derlenmesi ve kalitelerinin artırılması gerekmektedir. Kullanılmakta olan verinin kalitesi, bilgi göstergeleri açısından mevcut durumu ve bilgi sermayesinin artmasına katkı sağlayacak etkin ve etkili politika araçlarının belirlenmesi açısından belirleyici rol oynamaktadır. Dolayısıyla, Türkiye'deki bilgi göstergelerinde zaman serisi analizlerinde Ar-Ge harcamalarının ve bilişim teknolojileri verilerinin hem mikro hem de makro düzeyde daha kapsamlı veriler ile güncellenmesi ve yeniden yapılandırılması gerekmektedir.

- ***Bilgi ekonomisinin ana kaynağı "insan sermayesi"***: Her üç makalenin sonuçları insan sermayesinin incelenen bilgi sütunları (boyutları) arasında en önemlisi olduğunu göstermektedir. Sonuçlarımız, insan kaynaklarını bilgi birikiminin merkezine yerleştiren Mincer (1958), Becker (1962) ve Forray'ın (2004) argümanlarını desteklemektedir. Ayrıca, insan sermayesi diğer bilgi sütunlarının etkin ve efektif kullanımını belirlemektedir. Mevcut bilgiyi tam olarak sindirebilmek ve kullanabilmek için beşeri sermayenin kalitesi düzeyi ülkelerin teknolojik kabiliyetlerini belirlemektedir.

Birinci makalede beşeri sermaye OECD ülkeleri arasındaki gözlemlenen ekonomik büyüme farkının en önemli faktörü ve lider ülkeden teknolojiyi alıp uygulama ve taklit etme kabiliyetini belirlemektedir. İkinci makalede de beşeri sermayenin Türkiye'nin ekonomik performansında, 1963-2010 döneminde, önemli bir unsur olduğu gözlenmiştir. Üçüncü makalede de geriden gelen firmaların lider firmaları yakalama süreçlerinde beşeri sermayenin en belirleyici faktör olduğu sonucuna ulaştık. Firma düzeyinde, Ar-Ge'nin önkoşulunu kalifiye insan kaynağı oluşturmaktadır. Beşeri sermaye aynı zamanda firmaların Ar-Ge kabiliyetlerini şekillendiren en temel faktördür. Beşeri sermayenin kalitesi hem firmaların hem de ülkelerin Ar-Ge kabiliyetini belirleyen en önemli unsurdur. Ayrıca, beşeri sermaye bir ülkenin veya firmanın "yakalama tuzağına" düşmemesinde rol oynayan en büyük bilgi sütunudur.

Bu sonuçlar ışığında bilginin ekonomik büyüme üzerine etkisini mevcut insan sermayesinin belirlediğini görmekteyiz. Diğer bir deyişle bir ülkenin veya firmanın bilgi birikiminin merkezinde beşeri sermaye yer almaktadır.

Bu nedenle, en önemli politika önerimiz insan sermayesinin geliştirilmesine öncelik verilmesidir. Ancak, bunu başarmak için temel eğitimin bir göstergesi olan "okul kayıt oranları" gibi basit politika araçları yeterli olmamaktadır. Hiç şüphesiz temel eğitim öğrenme kapasitesini ve bilgileri kullanmak için gerekli ancak günümüz teknolojilerinin gelişmiş ve karmaşık yapısını anlamak için yeterli değildir.

Uluslararası düzeyde en güncel teknolojileri kullanabilmek veya üretebilmek için ülkelerin mühendislik ve bilimsel alanlarda yüksek düzeyde öğrenime sahip insan sermayesine gereksinimleri vardır. Beşeri sermayenin kalitesini artırmaya yönelik farklı yöntemler kullanılabilinir. Örneğin, üniversiteleri uluslararası bağlantı kurmaya teşvik eden programlar yerel ekonomilere uluslararası bilgilerin transferini sağlayacaktır. Bu nedenle, politika yapıcılar güçlü yüksek öğrenim sistemlerinin kurulmasını desteklemeli ve teknoloji bakımından önde gelen ülkeler ile eğitim değişimi sağlayan bağlantıların ve programların oluşturulmasında öncülük etmelidirler.

Türkiye imalat sanayine (Makale 3) ilişkin analizimizde kalifiye ve kaliteli işgücünün artırılmasının sektördeki mevcut bilginin kullanılması ve firmaların Ar-Ge faaliyetlerinde önemli ve belirleyici olduğu belirlenmiştir. Doğu Asya ülkelerinin 1990'lı yıllardaki başarılarında, söz konusu ülkelerde teknik düzeyde eğitim veren liselerin yüksek kalitesinin oradan mezun olan işçilerin yeni teknolojileri adapte (kullanma) ve taklit etmelerinde belirleyici olmuştur. Bu nedenle önde gelen teknolojileri kullanma ve taklit edebilme yetisine sahip teknik düzeydeki lise mezunlarının sayısının artırılması, özellikle imalat sanayinin uluslararası düzeyde rekabet edebilirliği açısından önemlidir. Teknik liselerdeki eğitim kalitesinin artırılmasının yanı sıra, firmalar da mevut insan kaynaklarını geliştirme konusunda teşvik edilmelidirler. Bu nedenle firmaların insan kaynakları eğitimlerine yönelik teşvikler de oluşturulacak politikalara derc edilmelidir.

Bununla birlikte, bütün bu önlemlerin etkilerinin uzun vadede gerçekleşeceği göz önünde bulundurulduğunda, kısa vadeli politikalarda beyin göçünün engellenmesi ve başka ülkelerde çalışan yerli araştırmacıların geri dönmelerine yönelik teşvik politikalarına öncelik verilmesi gerekmektedir. Bunun yanı sıra, rekabetçi olunabilinecek ana sektörler belirlendikten sonra bu sektörün ihtiyaçları kapsamında kalifiye yabancı araştırmacılara cazip imkanlar sunularak onların getireceği dışsallıktan faydalanılmalıdır.

- ***Kilit kurumların belirlenmesi:*** Politika yapıcılar bilgi sütunların verimli kullanımının sağlanmasına yönelik öncelikli olarak kurulması gereken kurumlar tespit etmelidir.

Burada en önemli husus her ülkenin koşullarının kendine özel olduğudur. Bu nedenle başka bir ülkede başarılı olmuş bir politikanın bir diğer ülkede aynı başarıyı yakalaması pek mümkün değildir. Politikaların başarılarını ülkelere özel karakteristikler ve özellikle kurumsal yapılar belirlemektedirler

Helpman (1994) kurumların; yenilik ve yeni teknolojilerin geliştirilmesi, üretimin yeniden yapılandırılması ve yeni fırsatlardan yararlanılması ile fiziki ve beşeri sermaye birikiminin teşvik edilmesini etkilediklerini belirtmektedir. Bu nedenle, ekonomik büyüme sürecini kurumların Ar-Ge veya sermaye (fiziki ve beşeri) birikiminden daha fazla belirlediğinin altını çizmektedir. Helpman (2004) bir ülkenin büyümesinin değişimlere uyum yeteneğinin temelini oluşturan ekonomik ve siyasi kurumlara bağlı olduğunu belirtmektedir. Ancak, Helpman (2004) özellikle bir dönemde yapısı bakımından iyi performans sergilemiş bir kurumun diğer bir dönemde de aynı performansı göstermesinin beklenmemesinin ve bu nedenle kurumların yeniden yapılandırılması gerekliliğini vurgulamaktadır.

- ***Fiziksel Altyapı*: **İkinci makalenin sonuçları etkin bir şekilde işleyen bilişim altyapısı oluşturmanın uzun dönemli ekonomik büyüme üzerinde olumlu bir etkiye sahip olduğunu göstermektedir. Özellikle, ülke ve firma düzeyinde mevcut olan bilginin yayılmasında ve kullanılmasında, bilgi ve iletişim teknolojilerinin geliştirilmesi hayati bir öneme sahiptir.

Günümüzde mevcut olan neredeyse tüm üst düzey teknolojiler bilgisayar gibi bilişim teknolojilerine dayanmaktadır. Bunun yanı sıra, iletişim teknolojileri sanayileşmiş ülkelerdeki son gelişmeleri takip etme ve bilgi tabanı oluşturulmasına katkı sağlamaktadır. Ancak, internet gibi bilgi ve iletişim teknolojilerinin bazı yönlerinin, özellikle düşük gelirli ülkeler açısından ciddi altyapı yatırımları gerektirdiğinden dolayı finanse edilmesinin çok zor olduğu göz önünde bulundurulmalıdır. Ancak, gerekli altyapı hazırlandıktan sonra, bilişim teknolojileri bilgi transferi konusunda en etkin ve en az kullanım maliyeti olan yöntemdir. Bilişim teknolojilerinin en faydalı yönü bilgi transferi konusunda bir çok alternatifi ve yöntemi barındırmasıdır. Örneğin, özellikle gelişmekte olan ülkelerdekilerde, göreceli olarak daha az altyapı maliyetline sahip, mobil telefon sistemleri kullanılarak bilgi (internet) sistemlerine erişimi sağlayabilecek bir yöntemdir.

Mezo (sektör) düzeyde politikalar aşağıda yer almaktadır.

- ***Uygun sınır teknolojilerinin belirlenmesi:*** Birinci makale ülkelerin gelir düzeyine ve altyapılarına uygun sınır teknolojilerini hedeflemeleri gerektiğini göstermektedir. Hedeflenecek en gerçekçi (uygun) üst düzeydeki teknoloji belirlendikten sonra, politika yapıcılar, bu teknolojinin gerekliliklerine göre ülkenin teknolojik yeteneklerini güçlendirmek için araçlar geliştirmelidir.

- ***İçsel ve Dışsal Ağ iletişimlerinin güçlendirilmesi:*** Politika yapıcılar üniversiteler ve araştırma kurumları arasında güçlü bir ağ kurmak için yatırım yapmalı ve sınır teknolojilerine sahip ülkelerle eğitim değişim ağları oluşturmak için girişimlerde bulunmalıdırlar. Örneğin, İsrail, yüksek teknoloji sektörünü en iyi üniversite sistemlerinden biri ile desteklerken aynı zamanda akademik ve yazılım geliştirme konusunda ileri düzeyde olan ülkeler ile (örneğin Amerika Birleşik Devletleri) eğitimde değişim bağlantılarına öncelik vermiştir (Berry, 2002). Bu nedenle, politika önermeleri işbirliğini (özellikle üniversite ve özel sektör arasındaki Ar-Ge aktivitelerinde) teşvik edici unsurları da kapsamalıdır. Bazı ülke araştırmaları, Ar-Ge aktivitelerinde bulunan ve elde ettikleri bulguları özel sektör ile paylaşan üniversitelerin olmasının ekonomilerin büyüme oranlarına önemli düzeyde katkı sağladığını göstermektedir.

Teknoloji merkezleri (örneğin tekno parklar) yukarıda bahsi geçen bilgi transferlerinin yer aldığı önemli kurumlardır. Politika yapıcılar, bu merkezlerin altyapı ve araştırma sonuçlarını paylaşmaları konusunda teşviklere öncellik vermelidirler.

Bu tezde yer alan makalelerin sonucuna göre **mikro (firma) düzeyindeki politika** önerileri aşağıda yer almaktadır.

- ***Kalifiye insan kaynaklarının desteklenmesi***: Üniversiteler ve araştırma merkezleri araştırmacılarının vasıflarını geliştirilmlerine yönelik farklı türlerde desteklerle teşvik edilmelidir. Araştırma enstitüleri, mevcut beşeri sermayelerini geliştirmeleri için teşvik edilmelidir. Örneğin, araştırmacılarının bilgi kapasitelerini geliştirmeleri için enstitülere ulusal veya uluslararası eğitim programlarına katılımın sağlanması konusunda teşvik verilmelidir. Bu tür programlar hem beşeri sermayenin kalitesini artıracak hem de araştırma merkezinin genel bilgi birikimine katkı sağlayacaktır. Ayrıca, araştırmacıların bu programlar kapsamında oluşturacakları ulusal veya uluslararası bağlantılar araştırma merkezine dışsal bilgi akışının oluşmasına veya mevcut uluslararası ağların güçlendirilmesine katkı sağlayacaktır. Araştırma merkezleri bilgi birikimlerini veya kapasitelerini artırmaları için yüksek düzeyde kalifiye yabancı veya yerli araştırmacıları istihdam etmeleri konusunda da maddi olarak desteklenebilirler.

- ***Yabancı Sermaye yatırımlarının desteklenmesi***: Yabancı yatırımcıları çekmek amacıyla gerekirse, ekonomik koşulların yanı sıra teknolojik ve bilimsel kapasite gözden geçirilerek revize edilmeli ve gereken önemler alınmalıdır.

Daha önce belirtildiği gibi, Ar-Ge sektöründeki yabancı sermaye yatırımının en önemli belirleyicileri teknolojik ve bilimsel kapasitedir. Bu kapasiteler, temel olarak nitelikli beşeri sermaye (akademik hem de endüstriyel), araştırma enstitüleri, fikri mülkiyet hakları ve bunların düzeylerine bağlıdır. Bu faktörlerin iyileştirilmesi gelen yabancı yatırımın artmasının yanı sıra yerli firmaların veya yerli Ar-Ge merkezlerinin de gelişmesine katkı sağlayacaktır.

Ar-Ge kabiliyetinin artırılmasına yönelik olarak politika yapıcılar hem kamu hem de özel araştırma merkezlerine veya kurumlarına finansal destek sağlamalı ve Ar-Ge faaliyetlerini destekleyici ve teşvik edici uygun bir ortamı oluşturmalıdırlar.

Böyle bir ortam, Ar-Ge, eğitimli beşeri sermaye ve etkin şekilde işleyen kurumsal altyapı gerektirmektedir. Örneğin, kamu ve özel araştırma enstitüleri, ancak Ar-Ge faaliyetlerini destekleyen uygun politikalar kapsamında faaliyetlerine devam edecek ya da yeni araştırmalara yöneleceklerdir. Daha somut örnek verecek olursak, fikri mülkiyet haklarının yenilikleri koruması ve bu uygulamanın düzeyi girişimcilerin ve bilim adamlarını Ar-Ge faaliyetlerinde bulunmalarında belirleyici rol oynamaktadır. Bu nedenle, mucitlerin telif haklarının sağlanması politika yapıcıların üzerinde hassasiyetle eğilmesi gereken konuların başında gelen diğer bir husustur.

Güçlü bir Ar-Ge altyapısı oluşturduktan sonra, ülke, yenilikçi kapasitesini artırmasıyla birlikte sırayla rekabet gücünü ve ekonomik büyüme potansiyelini artırma olanağına kavuşacaktır.

- ***Ekonomideki farklı aktörler arasındaki işbirliği ve koordinasyonun artırılması:*** Politikaların başarılı bir şekilde uygulanması için kamu ve özel kurumlar arasındaki işbirliğinin ve koordinasyonun sürekliliğinin sağlanması önemlidir. Ekonomideki farklı aktörler arasındaki etkileşim mevcut bilgi stokunun artırılmasında önemlidir. Bu nedenle politika yapıcılar ekonomideki farklı aktörler arasındaki işbirliğini teşvik eden önermelere de politikalarında mutlaka yer vermelidirler.

- ***Uluslararası işbirliklerinde bürokrasinin azaltılması:*** Zorlu bürokrasi süreçleri ve diğer idari zorluklar kamu yardımını içeren politikaların en önemli kısıtlarının (dezavantajlarının) başında gelmektedirler. Bu tür zorlukların kaldırılması hem firmaları hem de araştırma merkezlerini uluslararası işbirliğini artırmaları konusunda teşvik edecektir.

Özetle, mevcut bilgiye erişim veya bilgi stokuna sahip olmak ekonomik büyüme üzerinde tek başına olumlu bir etki oluşması açısından yeterli değildir. Bilgi stokunun ülkelerin ekonomik büyüme ve yakalama süreçlerinde etkili olmalarını sağlayan unsurlar söz konusu ülkenin veya firmanın "adaptasyon kapasitesi" ve "sosyal kapasitesi"dir. Özellikle az gelişmiş ülkeler için bilgi kapasitesinin geliştirilmesi uzun dönemli bir süreçtir ve dolayısıyla gelişmiş ülkeleri yakalama süreçleri de hem çok zorlu hem de uzun dönemli bir süreçtir. Bu nedenle, ileride olan ülkeleri yakalamak için gerekli olan sosyal ve adaptasyon kapasitelerinin artırılmasında hem sabır hem de uygulanmakta olan politikaların sürekli gözden geçirilmesi, değerlendirilmesi ve revizyonu anahtardır.

Appendix 6. Curriculum Vitae

Family name(s): Utku İsmihan

First name(s) : Fatma Muazzez

Contact Information:
E-mail : fmutku@yahoo.com
Work Address : Ministry of Agriculture, Food and Livestock
General Directorate of EU and Foreign Relations
Department of EU Harmonization

1. Education

Institution (Date from – Date to)	Degree(s) or Diploma(s) obtained
METU (2016)	Ph.D. in Science and Technology Policies
University of York (2001)	MSc in Economics
EMU (1995)	MSc in Economics
EMU (1994)	B.B.A.

2. Language skills (indicate competence on a scale from 1 (basic) to 5 (excellent)

Language	Reading	Speaking	Writing
Turkish	Mother language		
English	5	5	5

3. Present position: Ministry of Food Agriculture and Livestock- Senior EU Expert

4. Certificates obtained

2013	Certificate on Communication and Negotiation: Intra-Cultural Communication, University of Ankara (ATAUM)
2009	WTO Basic Training Certificate (WTO e-trainning)
2009	Certificate of Terminology Expert, University of Hacettepe, Ankara
2006	Certificate of Negotiation Techniques, University of Ankara (ATAUM) and British Council
2005	How to operate in Brussels Certificate, Colingendale Institute, Netherlands
2003	Certificate of Trainer of Trainers of Nice Agreement, Ankara
2001	Certificate of EU-TR Customs Union, College of Europe, Brugges, Belgium
2000	Certificate of EU Common Agricultural Policy Expert, University of Ankara (ATAUM).
1999	Certificate of Basics on European Union, University of Ankara (ATAUM)
1989	City & Guilds of London, Computer Programming, Dublin, Ireland

5. Professional experience

Date from – Date to	Location (City/Country)	Institution & Reference Person (Name/Surname and contact details	Position
1998-today	Ankara/Turkey	Ministry of Agriculture	EU Expert
1997	Ankara/Turkey	Prime Ministry	Translator
1995-1996	Nicosia/TRNC	Near East University	Lecturer
1994-1995	Famagusta/TRNC	Eastern Mediterranean Uni.	Research and Teaching Assistant
1989-1990	Ankara/Turkey	Ministry of Foreign Affairs	Computer Expert

6. Specific experience in Current Position:

- Coordinator: Department of Economic and Technical Affairs, Research and Statistics Working group (Representing the Ministry in the FTA Meetings between Turkey and various other countries, leading and conducting various research on agricultural and economic issues)
- As an EU Expert:
  - Head of the Milk and Dairy Products Working Group of Chapter 11: 2005-2010
  - TAIEX contact point of the Ministry: 2005-2010
  - Translation Harmonization Contact Point of the Ministry: 2008-2010
  - Chapter 11. Introductory and Detailed Screening: The coordination of the Milk and Dairy products and presenting this topic in the commission and replying to both oral and written questions of the EU Commission on the subject
  - Thesis Supervision: Supervision of Assistant EU Expert Serkan YIKARBABA Thesis on "The implementation of the EU Law in the National Courts of the Member States"
  - Thesis Supervision: Supervision of Assistant EU Expert Derya DAĞDELEN "Global Bio-fuel Policies and Evaluation from the perspective of EU and Turkey"
  - Organizing and Taking Part in various International Meetings at Ministerial and Expert Levels

7. Publications and Working Papers

<u>Publications</u>

"Globalization of National Economies, 1975-2005" (with H. Olgun and M. İsmihan), International Research Journal of Finance and Economics, Vol. 1, Issue 14, 2008, pp.68-81.

"Tarım Politikalarının Başarıyla Uygulanmasında Değişmeyen Unsurlar", Türktarım Dergisi, Kasım-Aralık 2013.

"Avrupa Birliği Süt Paketi", Uzman Gözüyle Tarım Gıda ve Hayvancılık Bakanlığı, Mayıs, 2014.

"Avrupa Topluluğu Süt ve Süt Ürünleri Politikası", *Gıda Mühendisliği Dergisi*, No. 10, Eylül 2001, Ankara, 6-9.

"Kuzey ve Güney Kıbrıs Ekonomilerinin Karşılaştırmalı Analizi", *Adım*, Vol.1, No.3, July-September,1996, Lefkoşa: Sultan Matbaası, 1-12.

<u>Working Papers And Conference Papers</u>

"The Role of Knowledge on Economic Growth: The Case of Turkey, 1963-2010" Science and Technology Studies Research Center, TEKPOL Working Paper Series, METU, STPS-WP-12/07, 2013.

"A Proposed Index for Measuring 'Globalization' of National Economies", (with M. Ismihan and H. Olgun), METU Economic Research Center (erc) Working Papers in Economics, No.98/5, 1998. (METU)

"Information and Communications Technology and Economic Growth: An Analysis From a Developing Country Perspective", EconAnadolu International Conference, Eskişehir, June 2011.

"Kalkınmakta Olan Ülkelerde Firmaların Arge Kararlarını Belirleyen Unsurlar: Türkiye Örneği", (with Teoman Pamukçu), YEBKO National Conference, İzmir, September 2009.

"The Role Of ICT And ICT Clusters On Economic Growth: Lessons and Policy Issues", TED International Conference, Ankara, June 2009.

“Factors Influencing The R&D Performance Of Private Sector In Developing Countries: The Case Of Turkey”, (with Teoman Pamukçu), EconAnadolu International Conference, Eskişehir, June 2009.

“An Analysis of e-Government From An Institutional Perspective: The Case Of Turkey”, ICEGOV National Conference, Ankara, March 2009.

“‘Globalization’, Regionalization from a Development Perspective: Implications for Turkey”, (with M. Ismihan and H. Olgun) Presented in the METU Conference on Economics / II , Organized by Economic Research Center, METU, Ankara, Turkey, September 9-12, 1998.

Appendix 7. Tez Fotokopisi İzin Formu

ENSTİTÜ

Fen Bilimleri Enstitüsü ☐

Sosyal Bilimler Enstitüsü ☑

Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

YAZARIN

Soyadı : Utku İsmihan
Adı : Fatma Muazzez
Bölümü : Bilim ve Teknoloji Politikası Çalışmaları

TEZİN ADI (İngilizce): Essays on the Impact of Knowledge on Economic Growth

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 (1) yıl süreyle fotokopi alınamaz. ☑

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: