INTERNATIONAL TECHNOLOGY DIFFUSION CHANNELS AND TOTAL FACTOR PRODUCTIVITY CONVERGENCE: A STATISTICAL AND COMPARATIVE ANALYSIS OF DEVELOPING COUNTRIES

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ABSTRACT

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It is well known that differences in productivity levels explain a significant portion of international income per capita variation and that technology is one of the main determinants of productivity levels. Expanding technology levels is possible either through autonomous technology creation, which is usually related to research and development (R&D) activity, or technology diffusion. Since most of the technology creation happens in developed and rich countries, international technology diffusion plays a major role in technology absorption in developing countries. It offers them great opportunities for economic growth.

This thesis aims to explore the extent to which developing countries benefit from foreign technology, the diffusion mechanisms/channels involved, the factors that shape their absorption capabilities, and the sources of heterogeneity in the technology spillover gains by comparing with each other. Moreover, the other purpose of this thesis is to evaluate the role of technology diffusion in total factor productivity (TFP) convergence in developing countries through a comparative analysis.

Two equations are estimated for analysis: the first model evaluates the relative effects of various diffusion channels and heterogeneity factors on TFP, and the second assesses the impact of international technology diffusion on TFP convergence between developed and developing countries. The analysis covers 46 developing countries and G7 countries from 2000 to 2019. The overall results demonstrate that, although the benefits of technology diffusion vary depending on the diffusion channels and some country-specific characteristics, international technology diffusion is essential in helping developing countries close the productivity gap with developed ones.

Keywords: International Technology/Knowledge/R&D Diffusion/Spillovers, Total Factor Productivity, Convergence, Economic Growth

ÖZ

ULUSLARARASI TEKNOLOJİ YAYILIM KANALLARI VE TOPLAM FAKTÖR VERİMLİLİĞİ YAKINSAMASI: GELİŞMEKTE OLAN ÜLKELERİN İSTATİSTİKSEL VE KARŞILAŞTIRMALI ANALİZİ

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Teknoloji, ülkelerin verimlilik seviyelerinin ana belirleyicilerinden biri olup ülkelerin verimlilik seviyelerindeki farklılıklar ise kişi başına düşen uluslararası gelir değişkenliğinin önemli bir bölümünü açıklamaktadır. Bir ülkedeki teknoloji gelişimi, genellikle Ar-Ge faaliyetleri sonucu ortaya çıkabileceği gibi uluslararası teknoloji transferi ile de ortaya çıkması mümkündür. Teknolojik faaliyetlerin büyük bir kısmı gelişmiş ve zengin ülkelerde gerçekleştiği için uluslararası teknoloji yayılımı, gelişmekte olan ülkelerde teknoloji seviyesinin gelişmesinde önemli bir rol oynamakta olup, bu ülkelerin ekonomik büyümesi için büyük önem arz etmektedir.

Bu tez, gelişmekte olan ülkelerin yabancı teknolojiden ne ölçüde yararlandığını, bu ülkelerdeki teknoloji difüzyon mekanizmalarını/kanallarını, bu ülkelerin yabancı teknolojiyi özümseme yeteneklerini etkileyen faktörleri ve uluslararası teknoloji yayılımı kazanımlarını etkileyen heterojenlik kaynaklarını, birbirleri ile karşılaştırarak keşfetmeyi amaçlamaktadır. Ayrıca, bu tezin diğer amacı, gelişmekte olan ülkelerde

uluslararası teknoloji yayılımının toplam faktör verimliliği (TFV) yakınsaması üzerindeki rolünü karşılaştırmalı bir analizle incelemektir.

Analiz kısmı için toplamda iki model tahmin edilmiştir: İlk model, çeşitli teknoloji yayılma kanallarının ve heterojenlik faktörlerinin TFV üzerindeki göreceli etkilerini değerlendiririrken, ikinci model ise, uluslararası teknoloji yayılımının gelişmiş ve gelişmekte olan ülkeler arasındaki TFV yakınsaması üzerindeki etkisini değerlendirmektedir. Yapılan değerlendirmeler 46 adet gelişmekte olan ülkeyi ve G7 ülkelerini kapsamakta ve 2000-2019 yılları arasını incelenmektedir. Genel olarak sonuçlar, teknoloji yayılımının faydalarının yayılma kanallarına ve ülkeye özgü bazı özelliklere bağlı olarak değişmesine rağmen, uluslararası teknoloji yayılımının, gelişmekte olan ülkelerin gelişmiş ülkelerle olan verimlilik farkını kapatmaları noktasında önemli bir rol oynadığını göstermektedir.

Anahtar Kelimeler: Uluslararası Teknoloji/Bilgi/Ar-Ge Yayılımı, Toplam Faktör Verimliliği, Yakınsama, Ekonomik Büyüme

To My Family

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Economic growth has several elements and depends on the population growth rate, technological expertise, savings amount, resource distribution, economic organization structure, and other pertinent elements. In the neoclassical theory, technological development has generally been considered an external factor, and the main engine of growth has been seen as capital accumulation. However, endogenous growth theory has introduced the concept of innovation-driven growth. The emerging endogenous growth models emphasized the role of profit-driven enterprises' innovation endeavors as a primary driver of technological advancement and productivity growth.

The endogenous growth models emphasize two key characteristics of technology as an economic asset. One notable characteristic of technology is its non-rivalrous nature, whereby multiple users can benefit simultaneously from its utilization. The second characteristic pertains to the division of technology returns into private and public components. This statement indicates that technology not only generates profits for domestic countries but also generates positive externalities that benefit countries other than the one that invented the technology (Keller, 2004). That is, through international technology diffusion[1], novel technologies, and innovations spread from countries of origin (i.e., technology frontiers) to countries that have adopted them.

Developed countries have the capability to conduct their own R&D endeavors independently through a highly skilled workforce (Gomulka, 1990). Consequently, developed nations are at the forefront of new technology since they have a track record of creating and innovating new technologies. On the other hand, developing nations

[1] In this paper, technology diffusion, technology spillovers, R&D spillovers and knowledge spillovers are used interchangeably.

lack the ability to generate novel technological expertise. Typically, they have little capacity for conducting innovative activities, which are largely ineffective when executed by a workforce lacking advanced skills. Therefore, they require foreign technologies to augment their technical progress. In this respect, international technology diffusion from technology frontiers is highly crucial for developing countries.

Given the importance of technology spillovers from developed countries for the less developed countries' economic growth, it is essential to analyze how these spillovers occur and the effects of these spillovers. This analysis contributes to understanding the global disparities in per capita income and provides valuable policy recommendations for developing and transitioning countries participating in international markets.

As a result, the technology diffusion channels and their features are of importance in the literature on economic growth. The empirical investigation into the estimation of spillover effects between countries originated with Coe and Helpman (1995), which subsequently led to extensive research in many forms at the country, sectoral, and firm levels.

However, the majority of research in the existing literature has mostly concentrated on diffusion channels in developed nations. Although a few studies have investigated a group of both developed and developing countries, they have not made a distinction based on the degrees of development of these countries. Recently, there has been an increasing amount of research that has examined this differentiation. However, more studies still concentrate on developed countries compared to those that analyze developing countries.

Moreover, countries are prone to receive diverse advantages from the diffusion of foreign technology, which vary according to their trading patterns, level of openness, domestic conditions, and geographical localization. The stylized presentation of these facts implies some conjectures about the potential causes that may account for the differential benefits of technology spillovers among developing countries. This research also especially addresses this issue in the context of less developed countries.

Due to the significant impact of the technological gap on the progress of developing countries in catching up to rich countries, the literature has extensively examined the convergence of total factor productivity (TFP) as an indicator of technological progress. In other words, variations in productivity levels account for a substantial amount of the variances in per capita income among countries. For this reason, productivity convergence can be seen as a proxy for income convergence. At this point, since technology diffusion is a driving force for equalizing technological gaps between countries, productivity convergence is partially determined by the extent of worldwide technological diffusion.

When it’s all put together, "why growth rates differ" is closely linked to international technology diffusion. However, several studies in the literature primarily focus on this subject in industrialized countries or fail to differentiate between countries with varying levels of development. Therefore, the prospected contribution of this paper is that it analyses the relative effects of multiple diffusion channels on productivity and the variations in the capacity to absorb foreign technology by focusing on developing countries. Moreover, this paper also investigates the role of international technology diffusion in the productivity convergence phenomenon.

The rest of the study is organized as follows: In Chapter 2, some of the related definitions and basic concepts are given. In Chapter 3, a review of the literature on technology and economic growth approaches is presented. A review of the literature on international technology diffusion is represented in chapter 4. Chapter 5 gives a review of the literature on total factor productivity convergence. Chapters 6 and 7 show details about the dataset, the methodology used, and empirical results. Finally, the summary of the concluding remarks of the paper is given.

CHAPTER II

DEFINITIONS AND BASIC CONCEPTS

2.1 What Is Technology?

The phrase 'technology' is an inherently abstract and complex idea that poses challenges in interpretation, observation, and evaluation. (Blomström & Kokko, 1998). Understanding the nature of technology and what it consists of requires an in-depth debate on the concept of technology. Studies have shown that it's not easy to describe the idea of technology (Reddy and Zhoa, 1990). Thus, earlier literary works have given different meanings to the term technology.

Technology is simply known as the application of scientific knowledge for practical purposes. According to Dunning, technology is a source of information used to develop new products and services and increase the effectiveness of production and marketing of already-existing ones (Dunning, 1998, p.8). According to another view, technology is any kind of information, expertise, and method that either develops a new good or makes it possible to produce things already in existence more cheaply and with better quality (Seyidoğlu, 1998, p.103). The definition of technology, according to Mascus (2003), has been expanded to include “the required knowledge to get a specific production result through a specific manner of mixing or processing chosen inputs, which encompass manufacturing processes, intra-firm organizational structures, managerial strategies, and means of finance, marketing approaches, or any combination thereof” (Marcus, 2003).

Kumar et al. (1999) define technology as having two main components: a physical component, which includes products, equipment, tools, techniques, and processes, and an informational component, which encompasses knowledge in management, marketing, production, and functional areas. Therefore, some authors differentiate technology as “explicit knowledge,” which is defined as codified and transmittable knowledge, and "tacit knowledge," which is associated with "practical knowledge," which is not readily manifested, resolved, transferred, or overtly declared to another individual.

In this thesis, the term "technology" encompasses various elements such as product and production process technology, knowledge and skills like know-how, marketing, management, organization, foreign markets, and global production networks.

2.2 The Concept of Technological Progress

Technological progress, development, or innovation can be described as "The creation of new knowledge, the transformation of existing knowledge into economically significant new products and functions, or the giving of new shape to existing knowledge" (Edquist, 1997, p.14).

According to (Eaton & Kortum, 1996), the technological innovation process is simply the result of innovative activity efforts, which produce or create new knowledge. Technological progress occurs when innovation results in technical advancements and increases production efficiency with improved productivity of factors of production, all of which contribute to economic growth (see figure 2.1).

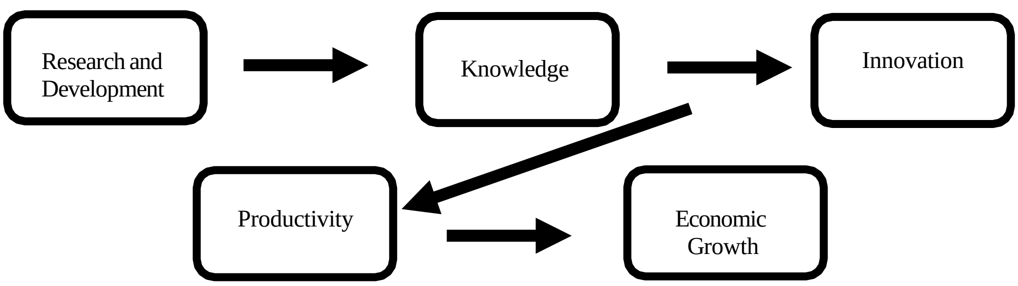

Figure 2.1 Technological Innovation Process

Source: By the author, based on ideas of Eaton and Kortum (1996)

Economic growth is a metric for measuring a country's development and advancement, and in economics, technological progress is widely recognized as the primary driver of economic growth (Mohamed et al., 2022). The recognition of the significance of comprehending the process of technological progress has been established for a considerable period, leading to the initiation of academic research dating back to the 1950s.

A considerable amount of empirical literature on technological progress and economic growth has consistently demonstrated that technological innovation is a vital driver of economic growth. The growth theories that have emerged after Adam Smith's time posit that economic growth is achieved through enhancements in productivity stemming from the division of labor and specialization. These theories emphasize the significance of technology, R&D, innovation, productivity, and international trade as fundamental drivers of economic growth.

Joseph A. Schumpeter, in his seminal work "The Theory of Economic Development," has underscored the significance of the notion of innovation in the advancement of capitalism. The significance attributed to the function and contribution of individual enterprises engaged in the process of "creative destruction" is crucial for understanding the economic progress of developed nations today (Ghosh, 2002).

The neoclassical school of thought originally recognized and examined the notion that technological progress serves as the major driver of economic growth. Through rigorous empirical investigations, neoclassicists agreed that technological changes outweighed other factors driving economic dynamics. However, the neoclassical growth hypothesis proposed by Solow (1956) and Swan (1956) posits that the rate of technological advancement is determined by a scientific process that is distinct from and unaffected by economic pressures. Accordingly, the neoclassical theory posits that economists can consider the long-term growth rate as an exogenous factor originating from outside the economic system (Howitt, 2010).

Since the 1980s, endogenous growth theory, as represented by Romer (1990) Grossman and Helpman (1991), has introduced innovation-driven growth. The endogenous growth theory has aimed to provide a comprehensive explanation for the phenomenon of long-run economic growth. This approach presents a theoretical framework for understanding technological change, a significant aspect of the neoclassical theory (Öztürkler & Bozgeyik, 2014). Endogenous growth models challenge the neoclassical perspective by proposing that economic considerations might influence the rate of technical progress and, subsequently, the overall rate of economic growth. The process commences with the recognition that technological progress is driven by innovations in the shape of new goods, processes, and markets, a significant portion of which stem from economic activities, and it results from the rate of investment, size of capital stock, and stock of human capital (Howitt, 2010). Therefore, the concept of long-run economic growth is internal to the economy.

The economic literature asserts that disparities in economic growth can be attributed significantly to variations in technological development across countries. It is widely acknowledged that sustained economic growth can only be achieved through continuous advancements in technology (Güven, 2014). Given the significance of technology progress in industrial growth, nearly every country is focused on monitoring technological changes. This concern is associated with technology policies like R&D, technology planning, and technology management.

Today, in the field of technological progress worldwide, there is a significant gap between developed countries and developing countries. Especially in this field, developing countries lag behind developed countries, and this gap is widening. The delays of developing countries in the field of technological development are also reflected in other areas of social life and the relations between developed countries and them. In this context, developing countries have a technological dependence on developed countries, and less developed nations must prioritize technological progress to bridge the gap with developed countries.

2.2.1 Measuring Technological Progress

Historically, developing countries have attempted to catch up to advanced nations regarding technology. During this "catching-up" phase of a national innovation system, any developing country is willing to compare its technology level to that of other nations. At this point, the outcomes of technological measurement can serve as a valuable point of reference for the formulation of catch-up efforts. Policymakers often utilize the measurement results as references for R&D policies and innovation strategies. The measurement of technology exclusively employed by developing countries. However, even countries that have made significant technological advancements must engage in comparative analysis with other countries to assess their relative standing (Kim, 2012).

Because technological progress is the main engine of productivity growth or economic growth, nations, international organizations, businesses, and other entities are among those who initiate the measurement of technological progress. However, unlike other things, technology is abstract and immaterial, and even specialists find it challenging to measure or estimate technological progress.

Analyzing a wide range of variables is required to measure technological innovation or progress in a nation. Here are a few illustrations of indicators frequently used to gauge a nation's technical advancement or innovation: R&D expenditure, patent applications, high-tech exports, technological capabilities, human capital, innovation index, and productivity.

A. R&D Expenditures

R&D, as the name suggests, consists of two similar but different processes. Research can be defined as new ideas, concepts, and principles; Development can be defined as the inclusion of these ideas into a good or service that can be sold in the market. There are two types of development: bettering an existing product or creating designs for a new product is called product development. The other is process development, which boosts output levels without compromising the quality of the final product. Both research and development produce unmatched things. (K. L. Phillips, 1993).

Economic growth and, consequently, the development of prosperity of nations and individuals arise from technological changes that occur through the introduction of new products and services, the development of more efficient production systems, and improvements in trade and management. R&D is the primary driver of technological change. Therefore, R&D plays a central role in improving economic growth and welfare.

The impact of R&D expenditures on economic growth has been the subject of many studies. In general, examinations of the relationship between R&D and economic growth begin with endogenous growth models. Romer (1986,1990) defines technological progress as the main engine of economic growth and investments in R&D as the main component of this technological progress. Grossman and Helpman (1990) also argue that R&D expenditures are vital for economic growth. Using US data, Aghion and Howitt (1992) point out the impact of the share of R&D expenditures in Gross Domestic Product on productivity and economic growth.

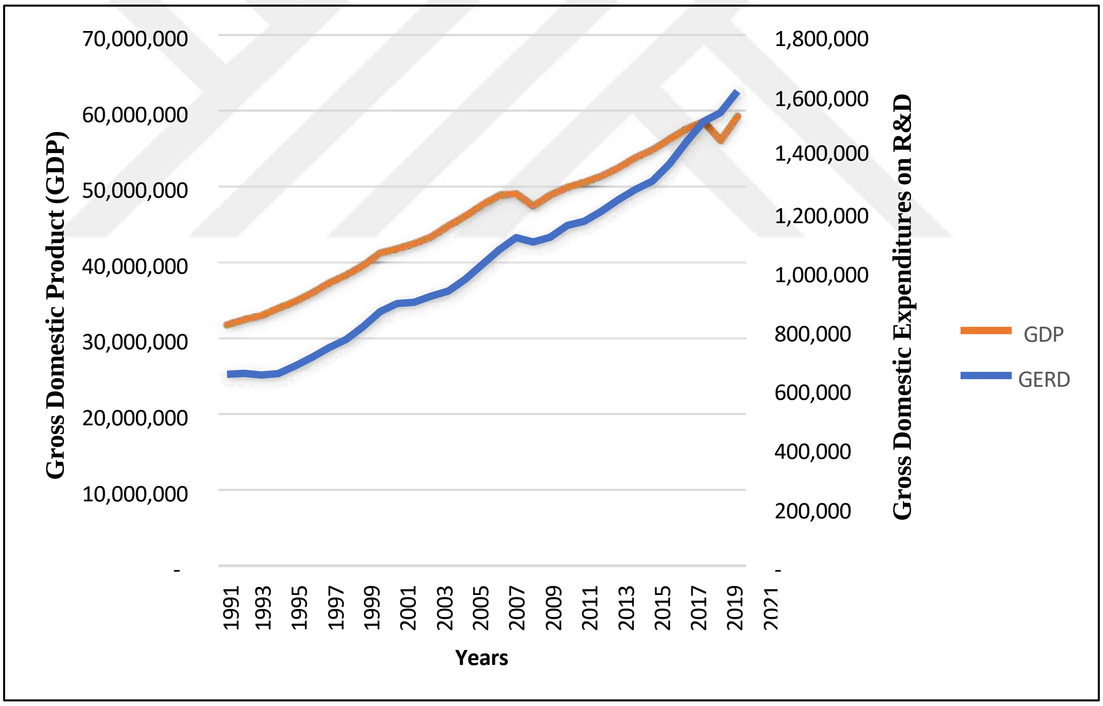

Figure 2.2 Gross Domestic Expenditures on R&D (GERD) and Gross Domestic Product (GDP) (1991-2021)

Source: Author's calculations based on OECD.Stat

Notes: GDP, PPP (constant 2015, in million US $) and GERD, PPP (constant 2007, in million US $) values are used for calculation.

Especially in the 21st century, the awareness of R&D's potential importance for long-term growth and living standards has also been reflected in countries' R&D policies (Becker & Pain, 2008). Figure 2.2 demonstrates the Gross Domestic Expenditures on R&D (GERD) and Gross Domestic Product (GDP) in Organisation for Economic Co-operation and Development (OECD) countries[2] between 1991 and 2021. In nearly thirty years, the GERD increased by 2,5 times and reached 1,6 trillion US dollars, the %2,7 of the 59,3 trillion dollars GDP of OECD countries. Moreover, very similar positive trends of GDP and GERD in these years prove the importance of R&D activities in economic growth.

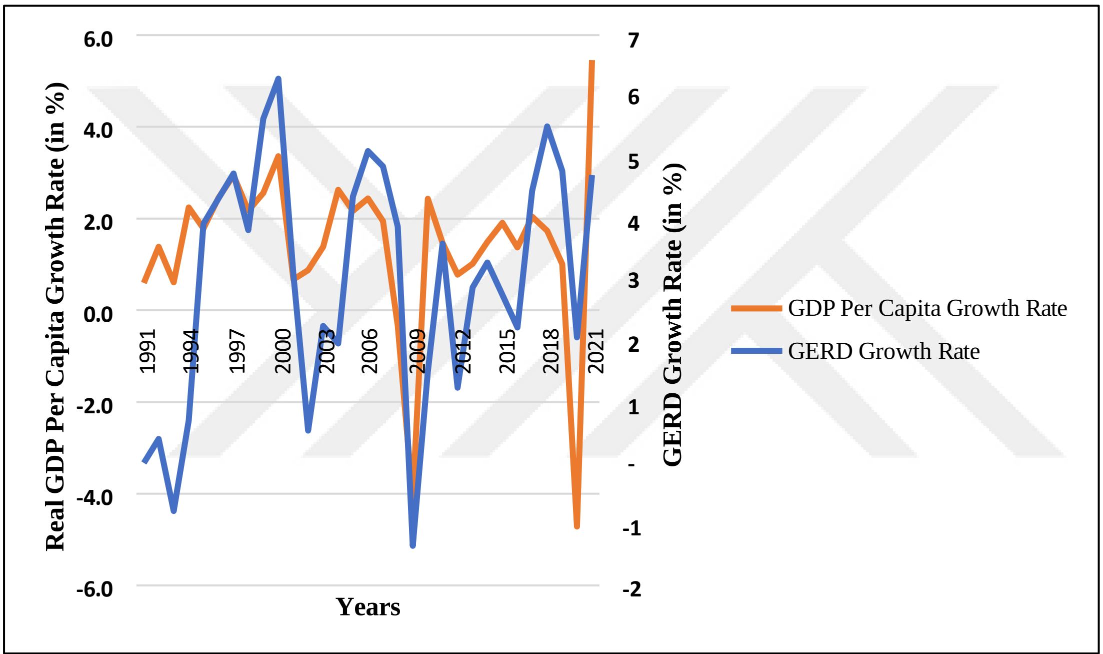

Figure 2.3 Real GDP Per Capita Growth Rate and GERD Growth Rate (Annual %, 1991-2021)

Source: Author's calculations based on OECD.Stat

Notes: GDP, Purchasing Power Parities (PPPs) (constant 2015, in million US $) and GERD, PPP (constant 2007, in million US $) values are used for calculation.

The reason why investment in R&D is one of the main strategies for technological progress and economic growth can also be seen in Figure 2.3, which shows the values

[2] Austria, Greece, New Zealand, Australia, Hungary, Norway, Belgium, Iceland, Poland, Canada, Ireland, Portugal, Chile, Israel, Slovak Republic, Colombia, Italy, Slovenia, Costa Rica, Japan, Spain, Czech Republic, Korea , Sweden, Denmark, Latvia, Switzerland, Estonia, Lithuania, Turkey, Finland, Luxembourg, United Kingdom, France, Mexico, United States, Germany, Netherlands

of real GDP per capita growth rate and GERD growth rate in OECD countries over 1991 and 2021. It is very clear that these two variables have significant and positive relationships over the years. Because the real GDP per capita is a proxy for average living standards or economic well-being, it is obvious that R&D activities are one of the main contributors to long-run economic growth.

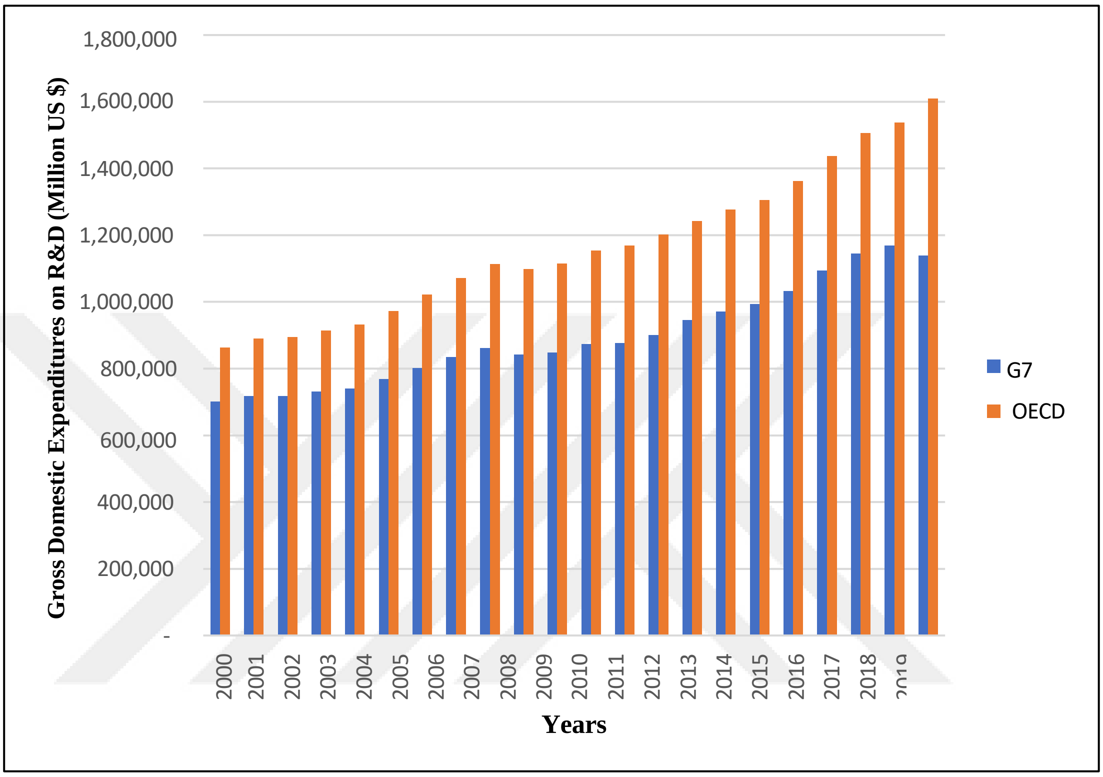

Figure 2.4 Gross Domestic Expenditures on R&D in OECD Countries and G7 Countries (2000-2021)

Source: Author's calculations based on OECD.Stat

Notes: Gross domestic spending on R&D is measured in US $ constant prices using the 2015 base year and PPPs.

However, as mentioned before, worldwide innovative activity is further concentrated in a few technologically leading developed countries. Moreover, The Group of Seven (G7[3]) countries are the major contributors to the R&D activities in OECD countries (see Figure 2.4). They accounted for %70,8 of the total R&D expenditures of OECD

[3] G7 countries are seven major industrial countries consists of United States (US), Canada, France, Germany, Italy, Japan, and the United Kingdom (UK).

in 2021. As a result, in this paper, the aggregated innovative activity of the G7 is employed as a proxy for the global technological frontier[4] and as the primary source of international technology spillovers.

B. Patent Applications

Technology has a public good characteristic where once produced, it is not exhausted by further use by others. It is generally assumed that the cost of the transfer technology is zero and that additional uses of the technology do not reduce its value. On these grounds, achieving optimal well-being requires making technology freely available to all potential users. This argument underlies claims that developing countries should have free (or cheap) access to the technologies of developed countries. However, the free diffusion of technology can thus encourage innovation in developing countries. The patent system tries to protect the property rights of the innovator while also allowing the technology to spread. In this context, high prices for technology and restrictions on its use are the basis for many developing countries to call for an international code of conduct for technology transfer and the revision of the international patent system (Dahlman & Westphal, 1983).

According to The World Intellectual Property Organization (WIPO), "A patent is a legally protected privilege given to an inventor for their creation, which can be either a product or a process that generally introduces a novel approach to doing something or presents an innovative technical resolution to a problem." Inventions result in patents. Patents result from inventive processes, specifically those intended to generate economic benefits. When examining present mental models, innovation is primarily associated with science and technology offering new opportunities. When patentable inventions result in new or improved products or processes, they create totally new industries.

In the 1970s, researchers utilized patent data to estimate economic production, employing the intermediate measure as a proxy (Acs et al., 2002; Griliches, 1990).

[4] The technology frontier distinguishes between technologies that are known and economically viable and those that are still undergoing experimentation or have not yet demonstrated commercial viability. It is the borderland of the current technologies (Thore, 1995, p. 45).

Subsequently, there has been a notable surge in the utilization of patent-based indicators among scholars and policy analysts. Patent data are utilized in several scientific fields and serve diverse objectives, such as analyzing a nation's level of innovation, assessing researchers' mobility, or quantifying technological progress (de Rassenfosse et al., 2013).

Patents are a reliable metric for assessing a nation's technological change, as they signify the tangible generation and diffusion of knowledge within productive endeavors. The close monitoring of technological innovation is facilitated by the ready availability and convenient accessibility to patent-related information, as well as the diligent updating of databases by Intellectual Property Offices and their connection to ingenuity. The examination of patent statistics reveals not only the increase of patent applications and grants at a national level but also provides insights into technology trends, prioritized or projected markets, and pioneering agencies within the field (Casanova, 2019).

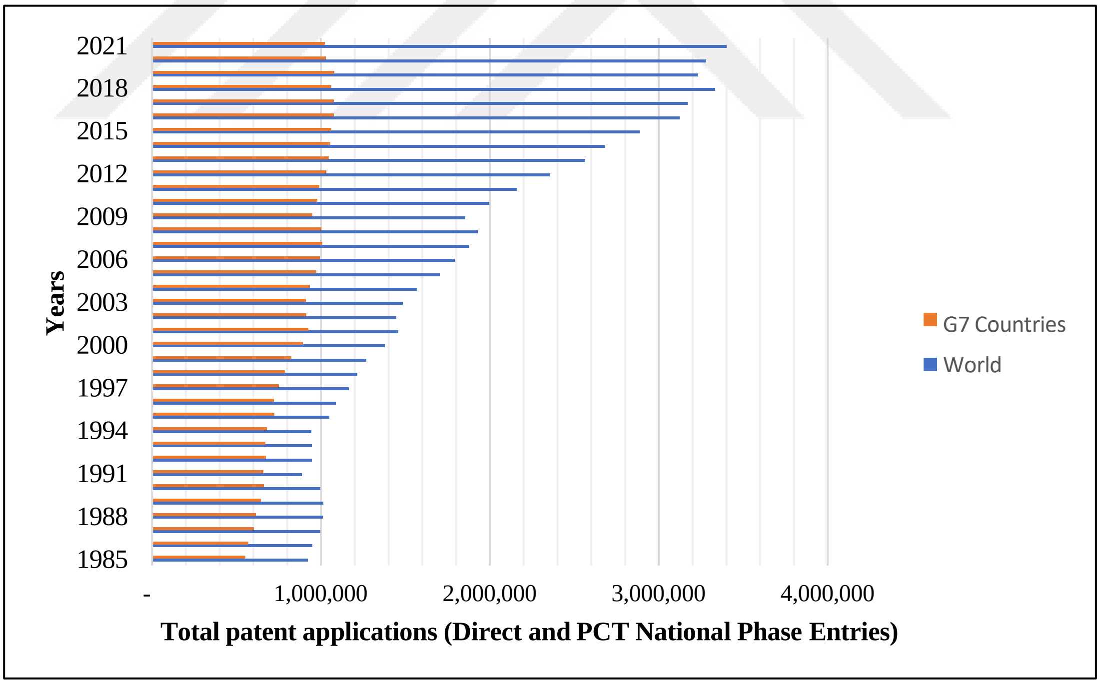

Figure 2.5 Total Patent Applications in the World and G7 Countries (1985-2021)

Source: WIPO

Recent years have seen a rise in the use of patent statistics as a measure of innovation and the analysis of innovation and the innovation process using patent data. Given this context and the rising interest among economists, management academics, and policymakers in innovation and technological change, it is said that research papers utilizing patent statistics have been growing more quickly than patents themselves, which have grown significantly over the past few decades (Nagaoka, Motohashi & Goto, 2010, p. 1085) .

As demonstrated in Figure 2.5, patent applications in the world are showing a positive trend. However, the distribution of patent applications is not even across countries. Patent applications in G7 countries have always had a major share in total applications (see Figure 2.5). In 2021, approximately %30 of total patent applications in the world were made in G7 countries. This situation is further proof that the development of technology has been concentrated in a few large industrialized economies.

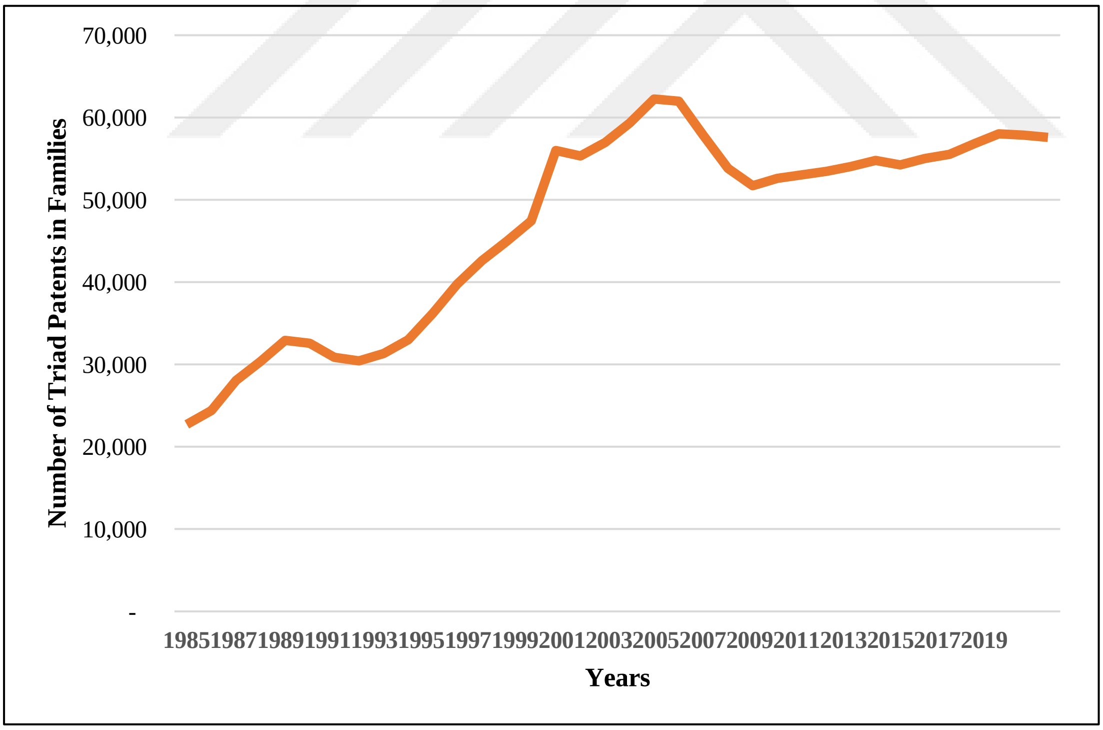

Figure 2.6 Triadic patent families in the World (1985-2020)

Source: OECD.Stat

In addition to the patent application, which can be considered one of the basic indicators of technological progress, triadic patent families are defined by OECD (Dernis & Khan, 2004) as the patent applications filed to protect the same invention at the US Patent and Trademark Office (USPTO), the Japan Patent Office (JPO), and the European Patent Office (EPO). Triadic patenting is particularly important as it indicates innovative performance, knowledge diffusion, and the internationalization of innovative activities. From Figure 2.6, it can be seen that the number of triple patents in the world is increasing regularly.

Figure 2.7 shows the international patent families, which are collections of publications or patent applications filed in several nations to safeguard a single innovation by a common inventor(s) (EPO). Figure 3.7 shows the patent applications by different patent offices. %47 of the total applications in the world are applied at the EPO, JPO, or USPTO, which is another proof of the uneven distribution of technological progress in the world.

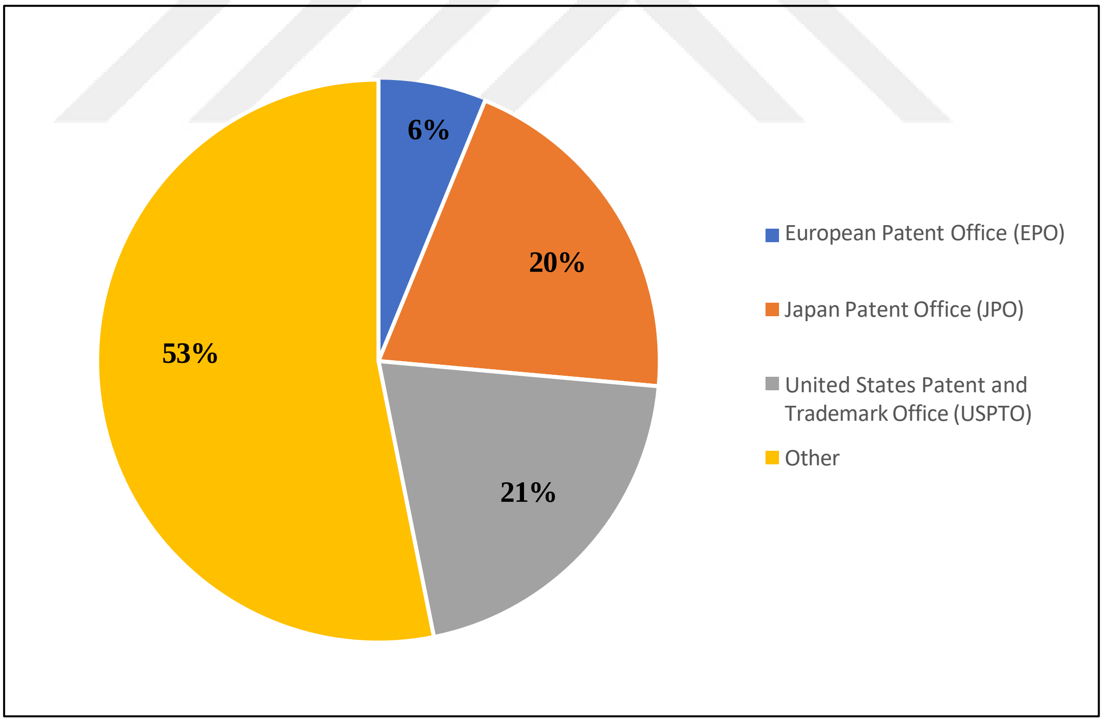

Figure 2.7 Patent Applications by Patent Offices (Average 1985-2021)

Source: Author’s calculations based on WIPO

C. Productivity

Productivity is generally described as a volume measure of output divided by a volume measure of input utilization (OECD, 2001). Productivity is one of the most closely monitored indicators of long-term economic prospects. An escalating level of productivity is critical for attaining sustained improvements in living standards. Moreover, the sole origin of enduring productivity enhancements is in technological progress. This is why productivity is an important measure of technological progress.

Productivity is a relatively uncomplicated indicator in theory. It defines the relationship between output and the inputs necessary to produce output. Despite its apparent simplicity, gauging productivity is fraught with complications. These issues are especially important when comparing productivity growth across countries, whether for the entire economy or for various industries, as well as when comparing international productivity levels (Schreyer & Pilat, 2001)

A wide array of productivity measurements exists. The selection amongst these options is contingent upon the intended goal of measuring productivity and, in several cases, the accessibility of relevant data. In general, productivity measurements can be categorized into two main types: single-factor productivity measures, which assess the relationship between output and a single input measure, and multifactor productivity measures, which evaluate the relationship between output and a combination of input measures (OECD, 2001).

One of the most common productivity measures is Multifactor or Total Factor productivity (TFP). The term TFP refers to the measure of the change in GDP that cannot be accounted for by changes in the amounts of capital and labor inputs utilized in the production process. The rise of TFP is derived from the enhanced utilization of labor and capital resources, such as advancements in production process management, organizational modifications, or innovation in a broader sense (OECD, 2008).

The expansion of total TFP presents society with the potential to enhance economically sustainable growth and thus promote long-term welfare improvement. Therefore, the comprehension of the factors that influence TFP growth is crucial in formulating policies that contribute to the improvement of growth prospects in developed countries.

Figure 2.8 shows the positive relationship between TFP and long-run economic growth. GDP per capita growth rate, which can be seen as a proxy for economic growth, and average TFP growth rate demonstrates a significant comovement over the years between 1997-2022. Therefore, we should anticipate periods of technological change to be accompanied by faster TFP growth.

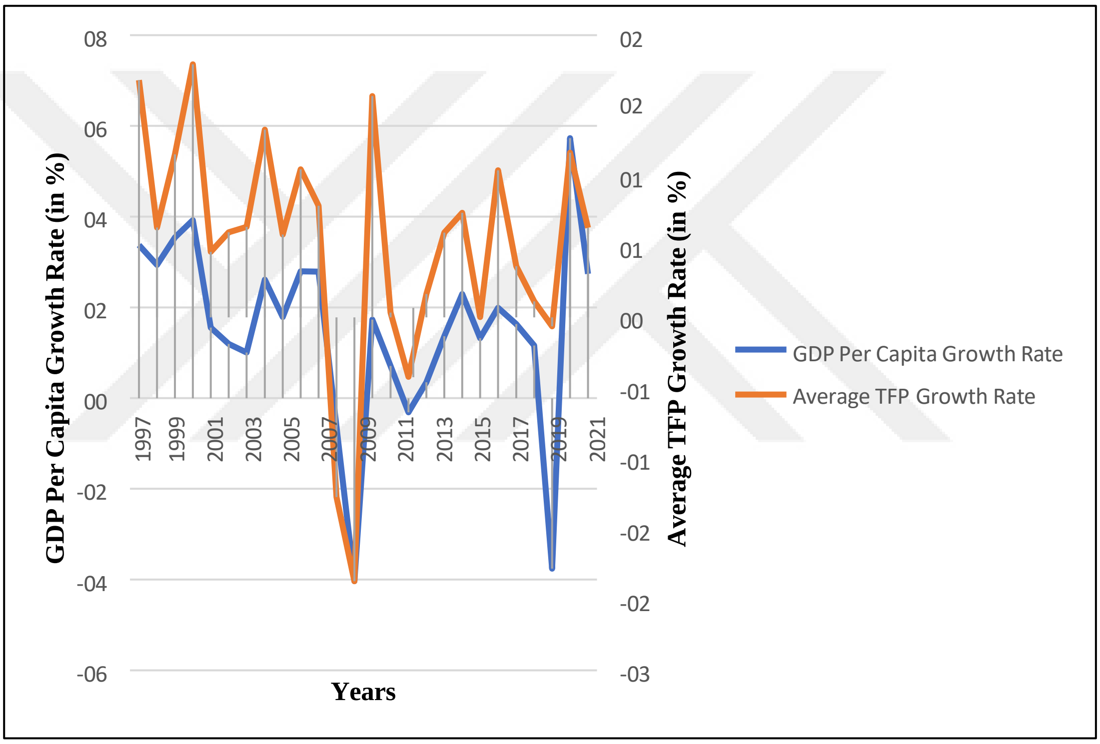

Figure 2.8 GDP Per Capita Growth Rate and Average TFP Growth Rate (in %, 1997-2022)

Source: Author's calculation based on the data from OECD.Stat

Notes: GDP, PPP (constant 2015, US $), and TFP Annual Growth Rate values of 24 countries[5] are used for calculation.

[5] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Japan, Spain, Switzerland, United Kingdom, Israel, Norway, Sweden, Netherlands, Luxembourg, Portugal, Italy, United States, Korea, New Zealand, Ireland.

The origins of the economic theory of TFP measurement can be traced back to the seminal contributions of Jan Tinbergen in 1942 and Robert Solow in 1957. There are various ways of measuring TPF; however, the most common ways are "The Growth Accounting Method" and "The Index Number Method". The growth accounting or residual method of TFP measurement can be found in Solow's articles published in 1956 and 1957. A production function is used to relate input measurements to output measurements. Any output growth not statistically correlated with the growth in measured inputs is presumed to be attributable to technological change. In addition to growth accounting, the index number method is a supplement and extension of growth accounting. Both entail indexes and similar issues. However, the index number approach does not require an aggregate production function, although a suitable index can be chosen using the economic approach for a specified production function. (Lipsey & Carlaw, 2004).

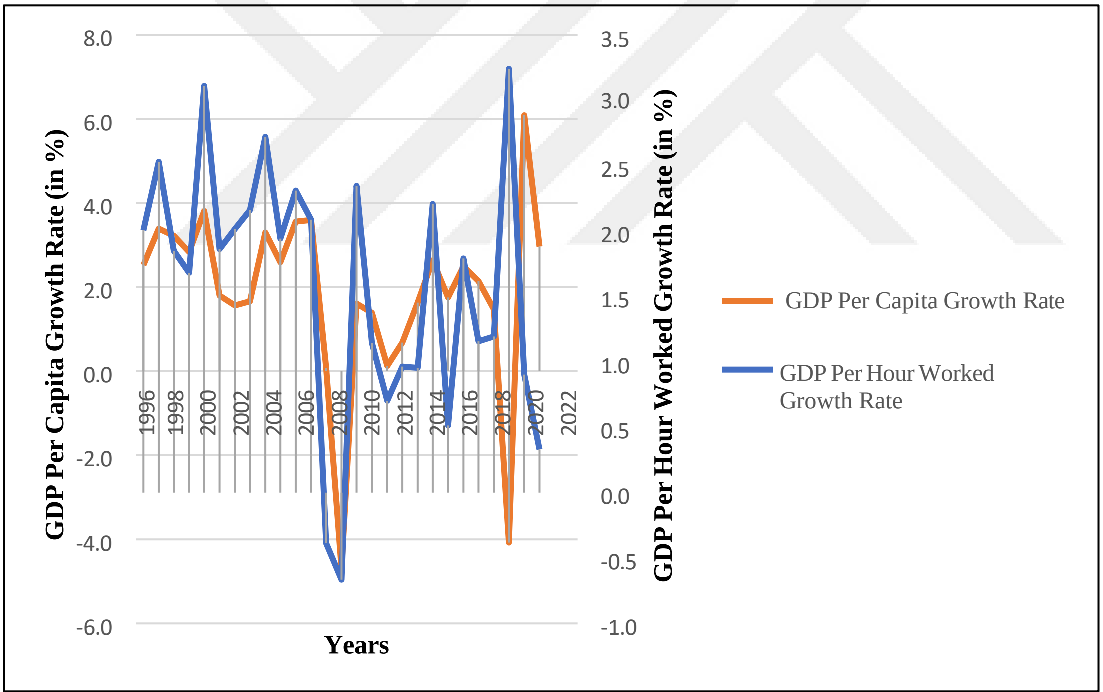

Figure 2.9 GDP Per Capita Growth Rate and GDP Per Hour Worked Growth Rate (in %, 1996-2022)

Source: Author's calculation based on the data from OECD.Stat
Notes: GDP, PPP (constant 2015, US $), and GDP Per Hour Worked, PPP (constant 2015, US $) values of 39 countries[6] are used for calculation.

[6] Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway,

As a result of its residual nature, TFP is rather counterintuitive. A more intuitive and more easily measured alternative is labor productivity. Labor productivity is a more intuitive and easily quantified alternative for productivity measurement. It also facilitates understanding of the role of technology as embodied in capital equipment (Coyle, 2019)

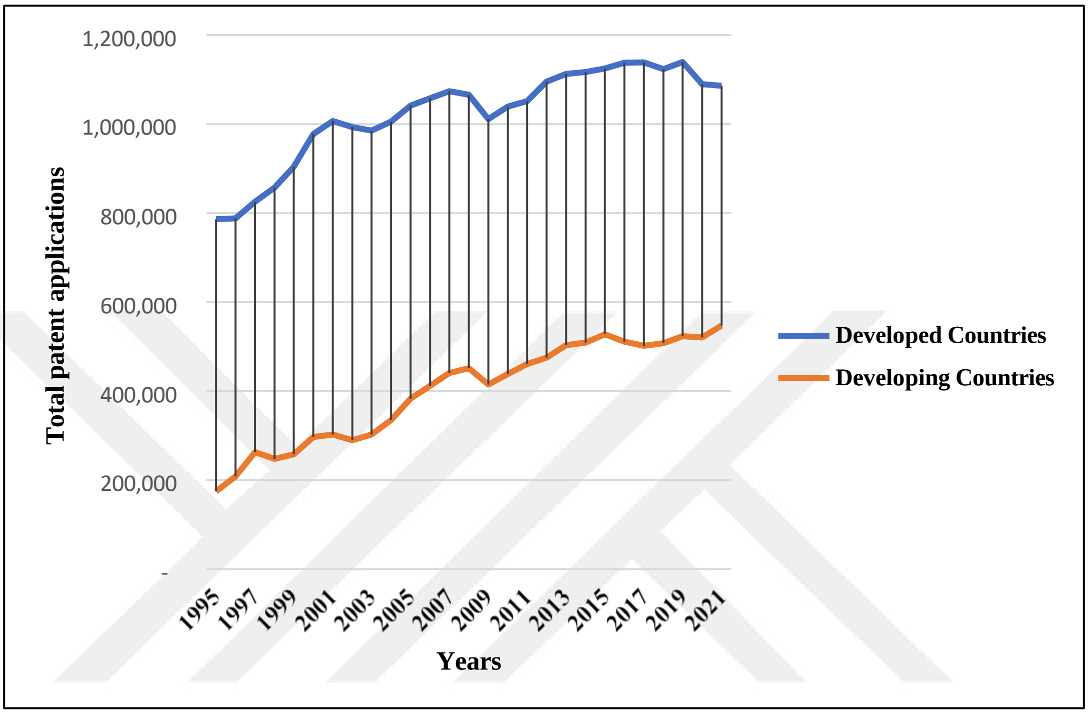

Figure 2.10 Total Patent Applications in Developed and Developing Countries (1995-2021)

Source: Author's calculation based on the data from WIPO
Notes: Total Patent Application values of 35 developed and 49 developing countries[7] [8] were used for calculation.

The concept of labor productivity can be described as the measure of GDP per unit of time worked, specifically per hour. Labor productivity changes are influenced by various factors, including changes in capital and intermediate inputs and technological, organizational, and efficiency changes within and between businesses. Additionally,

Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Türkiye, United Kingdom, United States, Chile, Israel, Slovenia Latvia, Lithuania, Costa Rica, Bulgaria, Croatia, Romania, Colombia.

[7] Developed and developing country classification is based on the United Nations (UN) country classification.

[8] See Appendix A for country list.

economies of scale, differing degrees of capacity utilization, and measurement mistakes also play a role in shaping labor productivity changes (OECD, 2001).

The positive relationship between labor productivity and economic growth can be seen in Figure 2.9, which shows the GDP per capita growth rate and GDP per hour worked growth rate between 1996 and 2022.

Figure 2.10 demonstrates the total patent applications in developed and developing countries. It is very clear that the gap between developed and developing countries is very serious. While the average annual total patent application in developed countries is nearly 1 million between 1995 and 2021, it is only 400,2 thousand in developing countries.

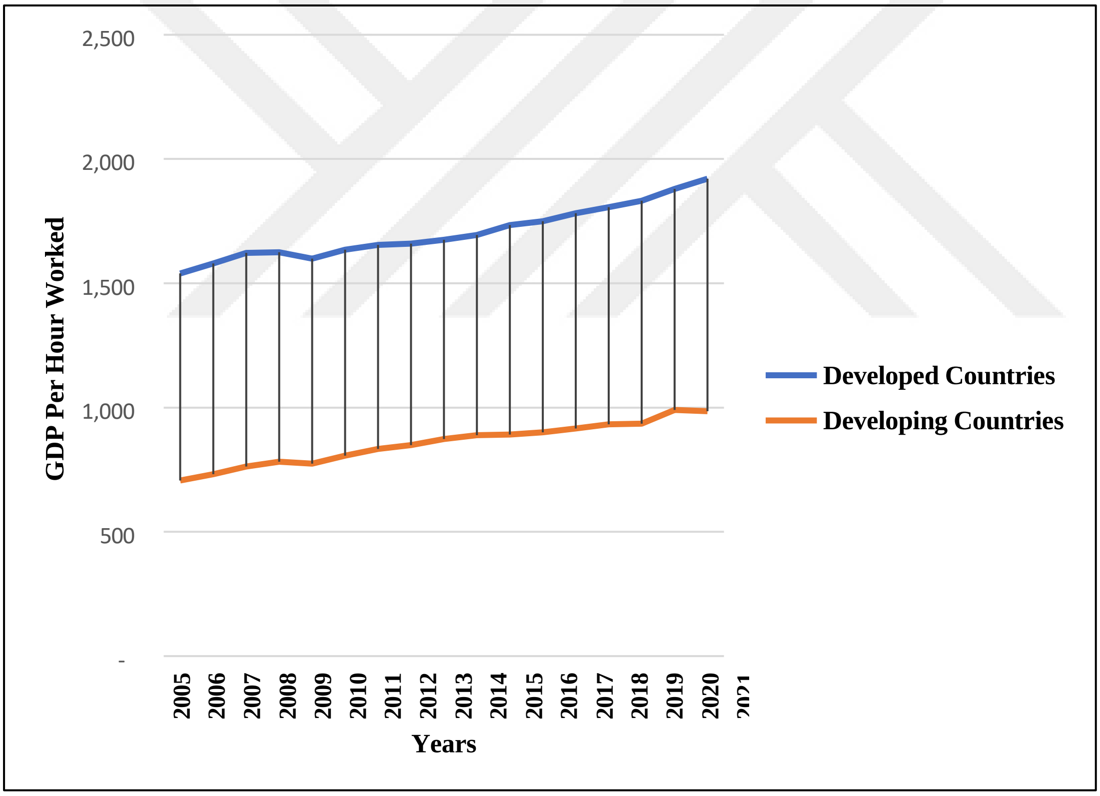

Figure 2.11 GDP Per Hour Worked in Developed and Developing Countries (2005-2021)

Source: Author's calculation based on the data from **the** Labour Organization (ILO)

Notes: GDP per hour worked (GDP constant 2017 international $ at PPP) values of 35 developed and 49 developing[9] countries were used for calculation.

[9] See Appendix A for country list.

Furthermore, figure 2.11 shows the GDP per hour worked, which is labor productivity, in developing and developed countries between 2005 and 2021. As in Figure 2.10, there is a significant gap between these country groups. In developed countries, the annual average GDP per hour worked is 1,7 thousand US dollars, whereas it is 856,5 US dollars in developing countries. However, the gap between patent applications is more severe than the gap between GDP per hour worked. This situation shows that the advantages derived from innovative activity, in this case patent application, are spread in a relatively more equitable manner around the globe, in contrast to the uneven distribution of patent applications. This empirical evidence strongly implies the international diffusion of technology across countries.

2.3 Technology Diffusion

As mentioned before, technology is a significant contributor to increases in income and standard of living. Historically, technological advancements have been confined to a small number of large industrialized nations. The degree to which one country's knowledge impacts other countries' productivity is a significant factor in determining the convergence of per capita income among nations and the rate at which this convergence occurs in the context of globalization. As a result, how technology diffuses across countries is critical to how global growth is generated and distributed among countries.

With endogenous growth literature, innovation-driven growth in an open economy context has been introduced, and this showed that an economy’s productivity level depends not only on its innovative activities, mainly R&D efforts but also on other countries’ innovation efforts. This has emphasized the importance of international technological knowledge spillovers for helping to explain countries’ productivity (see Figure 2.12). Technology diffusion is a process that transpires across several entities, such as countries, sectors, firms, or individuals, and can manifest in diverse manners. The investigation of spillover effects of technology across different countries was initiated by Coe and Helpman (1995), marking the inception of extensive subsequent studies in this area.

Technology or knowledge spillovers are commonly characterized as externalities, wherein individuals or entities are unable to fully capture all the advantages stemming from their own innovative activities. Technological spillovers refer to the situation where firms can obtain information generated by others without paying for it through a market transaction. The creators or current owners of the information have no legal means to prevent other firms from using the acquired information (Grossman and Helpman, 1992). Another definition of spillovers is "R&D spillovers refer to the involuntary leakage, as well as the voluntary exchange of useful technological information." (Steurs, 1995, p.2).

Technology diffusion or spillovers should not be confused with the concept of technology transfer. In this context, "technology transfer" refers to the practice of intentionally transmitting technology between countries or companies. In contrast, "technology diffusion" typically refers to the unintended transfer of technology.

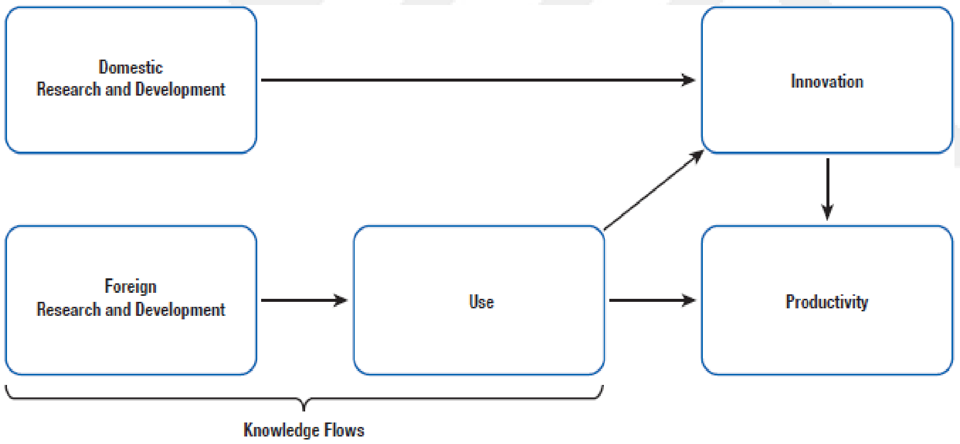

Figure 2.12 Technology Diffusion Process

Source: IMF

The nature of the underlying technology spillovers process significantly influences the identification and categorization of spillover effects. According to Los and Verspagen (2000), R&D endeavors can be categorized into two main types: process-oriented and product-oriented. The former aims to reduce manufacturing costs, while the latter focuses on developing new goods or enhancing the quality of existing ones. Moreover, Griliches (1979) has made a notable scholarly contribution by identifying and differentiating between two types of spillovers: knowledge spillovers (disembodied or direct spillovers) and rent spillovers (embodied or indirect spillovers). Rent spillovers refer to the diffusion of knowledge that occurs through the transactions of goods or investments, which can be considered indirect channels like international trade or Foreign Direct Investment (FDI).

On the other hand, pure knowledge spillovers do not require economic transactions and can occur through direct channels such as patents, licensing activities, technical conferences, or scientific papers. The quantification of disembodied spillovers presents challenges due to their intangible character. However, researchers commonly employ empirical methods that rely on proxies, such as measures of technological proximity.

2.4 International Technology Diffusion Channels

Domestic R&D activities and the overflow impacts of these activities, which is domestic technology diffusion, all contribute to a nation's productivity. However, when the impact of foreign innovative activities on domestic productivity was realized, how the knowledge of a nation transcends its borders and contributes to the productivity development of other nations started to be investigated.

Technology or knowledge spillovers typically happen through specific knowledge transmission channels. According to Coe and Helpman (1995), the overflow effect of foreign R&D efforts might spread to other nations through direct foreign capital investments and economic relations. These types of channels are considered indirect or knowledge embodied channels.

The most studied embodied international knowledge diffusion channel is international trade, especially import. New technologies, primarily originating from wealthy nations, are disseminated to other countries through imports from these nations, and more outward-oriented nations see higher productivity gains from foreign trade. Imports facilitate the acquisition of foreign technology by local enterprises, which can serve as a foundation for product innovation, process innovation involving advanced capital goods, and marketing and organizational innovation through efficient utilization of information (Kiriyama, 2012). According to Keller (2002), when engaging in foreign trade with technologically advanced countries, the developing country benefits from importing intermediate and capital goods rich in advanced technology. This facilitates the diffusion of technological knowledge and contributes to the accumulation of technological capabilities in the developing country.

Export is also a potential channel for international technology diffusion; however, this channel has been rather limited in prior studies. Since export sectors typically exhibit higher productivity levels than sectors that focus on domestic market output, export is widely recognized as a significant factor influencing economic growth and productivity expansion. Nevertheless, the concept of exporting as a means of diffusion of knowledge is not as readily apparent as the concept of importing. Moreover, most of the studies in the literature did not find strong evidence suggesting that exporters benefit from knowledge spillovers originating from their customers. However, there are also studies supporting the claim that export could also be a significant technology spillovers channel through the increasing body of literature concerning the phenomenon of "learning by exporting," which refers to productivity increases businesses enjoy when they begin exporting (Pietrucha and Żelazny, 2020).

In addition to import, another of the most famous embodied channels in the international spillovers literature is FDI. It is a major source of spillovers, usually due to multinational enterprises (MNEs) expansions that provide new technology and expertise to local markets. The productivity effects of domestic companies resulting from the presence of MNEs can be attributed to many causes. i) The phenomenon of demonstration effects refers to the adoption or imitation of technology by domestic firms from MNEs. ii) Vertical linkages, which involve the knowledge spillovers from MNEs to their customers or suppliers; iii) Labour turnover, where employees with newly acquired information frequently implicitly decide to leave MNEs and join local employers or start their own firms. (Krammer, 2014) iv) Multinational participation boosts competitiveness in the host country's market, forcing local enterprises to use their resources more efficiently or adopt new technologies.

On the other hand, the outcome of innovative activities primarily consists of intangible knowledge or information, which can be disseminated without requiring any investment or exchange of tangible products. Hence, it is crucial to acknowledge the significance of information spillovers that are not explicitly manifested in specific transactions. These types of channels are called direct or knowledge-disembodied channels, such as international patenting, the Internet, scientific publications, and international conferences. Assessing the precise impact of these direct channels has inherent challenges due to its intangible characteristics. Mostly, in literature, disembodied direct knowledge spillovers are commonly estimated by employing and modifying the measure of technological proximity proposed by Jaffe (1986, 1988).

The following chapters will present the details and associated studies of both direct and indirect international technology spillovers channels.

CHAPTER III

BRIEF LITERATURE REVIEW ON TECHNOLOGY AND ECONOMIC GROWTH APPROACHES

Economic growth theory is concerned with the difficulties of establishing dynamic equilibrium and seeks to determine the optimal utilization of existing production factors to achieve a sustainable long-term increase in real GDP per capita (Sredojević et al., 2016a).

The growth theories that emerged after Adam Smith's time posit that economic growth is achieved through enhancements in productivity stemming from the division of labor and specialization. These theories emphasize the crucial role of R&D, technology, innovation, productivity, and international trade in economic growth.

Technological progress holds a significant and prominent role in growth theories. Although these studies use very different analytical structures, they reach a common conclusion. The consensus emerging from these studies is that technology is one of the important factors determining economic growth. However, in most theories of economic growth, it is assumed that technological progress is exogenous. With the emergence of the New Growth Theory, which defends that technological progress is a crucial determinant of sustained benefits in living standards, the main economic theory held that technological progress is endogenous, which means that deliberate human attempts to create new technologies are what lead to it. (McDonough, 2017).

There is an extensive literature on the role of technology in economic growth. In this chapter, the place of technological progress in growth theories will be briefly examined.

3.1 Neoclassical Approach and Technological Progress: Solow-Swan Growth Model

A viewpoint suggests that the concept of economic growth theory, in its genuine form, originated around the mid-twentieth century, with the recognition of technological development as a crucial determinant of a country's economic growth (Solow, 1956, 1957). Neoclassical economists were the pioneers in unequivocally acknowledging and examining the concept of technological innovations as the primary catalyst for economic growth. Subsequently, several empirical studies were conducted to investigate this phenomenon further.

The neoclassical growth model, which Robert Solow and Trevor Swan created in the 1950s, is the basis for almost all studies of growth, and it attempts to understand analytically the basis of old and new theories of economic growth. Neoclassical growth theory focuses on capital accumulation and its connection with savings decisions. The most important neoclassical feature is the assumption of diminishing returns[10] to capital and labor (Hernández, 2003). This theory suggests no long-term economic growth in the absence of technological innovations.

The Solow-Swan growth model postulates that output production is accomplished by utilizing capital and labour factors, while maintaining constant returns to scale[11]. The outcome is either preserved or utilized. The capital stock refers to the aggregate amount of savings from prior periods, adjusted for depreciation. The labor supply is assumed to be constant, whereas saving is considered to be a fixed proportion of output. Assume that the initial capital stock of the economy is modest. The capital stock will increase each period until a constant state is reached in which saving equals depreciation. Along the path to the steady state[12], per capita consumption will rise, and

[10] In economics, the law of diminishing marginal returns states that once an optimal level of capacity has been reached, the addition of a further factor of production will yield comparatively smaller increments in output (Hayes, James, & Kvilhaug, 2022).

[11] The phenomenon known as "constant returns to scale" describes how, independent of the operation's size, the output of a production process rises in proportion to the inputs. Put another way, regardless of the magnitude of the activity, if the inputs to a production process are doubled, the output will likewise double. (Ansari, 2023).

[12] Steady state growth corresponds to the notion of long-run equilibrium. All variables, including output, population, capital stock, saving, investment, and technological progress, either increase at a constant exponential rate or remain constant during steady state growth. (Chand, n.d.).

the economy will expand. Once the stable state is attained, the per capita consumption remains constant, and growth ceases. Further expansion is only possible if there is an exogenous change, such as technological advancement, which elevates the output per unit of input.

Shortly, this analysis pertains to the impact of increased saving and investment on long-term economic growth. In the short term, a rise in saving and investment leads to a higher national income and product growth rate. However, it is posited that increased levels of saving and investment do not significantly impact the long-term pace of economic growth.

The primary drawback of neoclassical growth theory lies in its inability to tackle the inquiry of how technical progress occurs. It would appear that the neoclassical growth model does not describe the most crucial factor that determines the pace of growth because the technological advancements accounted for in the model are exogenous.

3.2 Schumpeterian Approach and Technological Progress

Joseph Schumpeter is generally viewed as a pioneer of modern innovation research, and many scholars who study innovation accept being classified as Neo-Schumpeterian. In Schumpeter's Theory of Economic Development, innovation is seen as the main mechanism behind economic dynamics (Lundvall, 2007).

According to Schumpeter, who made significant contributions to the evolutionary school of economics, technological development is a process that causes creative destruction by developing in the form of invention, innovation, and spillovers (Rosenberg & Frischtak, 1984).

According to Schumpeter's analysis, economic growth cannot be examined without considering innovations, technological competition, and technological development. In addition, he is very influential in the view that technological progress should be an internal, not external, variable of economic growth in a capitalist economy.

During the first half of the 20th century, neoclassicals believed that economic growth comes with the efficient allocation of resources. Their view of the market system is inherently stable and always moves to a stable single long-run equilibrium. However, at that time, Schumpeter's views were radical and anti-neoclassical. He deviated from these ideas and focused on the capitalist system's structural change and technological progress. He believes that the capitalist system is an evolutionary dynamic system, and it never converges to a stable long-run equilibrium point. Instead, it follows an equilibrium path that the economy follows. Thus, the economy is ever-expanding through this dynamic process.

His engine for economic growth is technological progress, which is not one jump progress, it was a chain of events that led to even further technological progress. This dynamic evolutionary process, called creative destruction, is the main source of this continuous technological change.

Creative destruction means the capitalist system creates new methods, products, or raw materials and pushes the old ones. In a capitalist economy, large firms compete to enjoy the monopoly profit. To get the profit, they innovate new things; however, each firm enjoys this profit temporarily because when a firm innovates something and benefits from it, another firm comes and destroys the old firm's innovation, creates its own innovation, and starts enjoying its profit until another firm comes with its own innovation (Chen & Chen, 2001)

In short, Schumpeter's ideas are very different than those of neoclassical economists. According to him, economic growth is characterized by structural change, which comes from the capital system's evolutionary process called creative destruction. This process provides constant technological progress, which is the main lever of economic growth.

3.3 Keynesian Approach and Technological Progress: Harrod–Domar Growth Model

The theories of American Evsey D. Domar and British Roy F. Harrod, who belong to the Keynesian school, are called the Harrod-Domar model because they simultaneously worked on the same subjects (Berber, 2006). In their studies, Harrod (1939) and Domar (1947) analyzed under what conditions England and the United States of America (USA) could reach full employment level of incomes in the long run and how this level could be sustained. This is a traditional theory of economic growth that describes the connection between economic growth, capital accumulation, and savings.

In the Harrod–Domar model of economic growth, there is an unlimited number of unemployed labor available in the economy, and the marginal product of capital is constant, which means that each additional unit of capital increases final output by the same amount because labor is always available for each additional capital. The model suggests that the new investment always increases the total capital stock (no depreciation), and the savings will always be channeled to investment projects efficiently in the economy. Thanks to the constant capital-output ratio, increases in savings always increase the rate of output growth.

The fundamental concept underlying the Harrod-Domar model posits that the expansion of an economy is contingent upon the quantity of capital accessible for investment, with the rate of capital accumulation being directly proportionate to the rate of savings. This model demonstrates that economic growth is primarily influenced by two key variables: the national savings rate and capital productivity.

The Harrod-Domar model serves as an alternative economic framework for elucidating the phenomenon of economic growth, in addition to the widely recognized Solow growth model. The Harrod-Domar model operates on the assumption that capital exhibits constant marginal returns. The Solow-Swan growth model, in contrast, exhibits a diminishing marginal return on capital.

Another distinction that can be observed is the impact of the savings rate. Solow's assumption posits that alterations in the saving rate yield transient impacts. However, the Harrod-Domar model exhibited a lasting impact (Nasrudin, 2022a).

The first of the most important criticisms of the Harrod-Domar model is that since it prioritizes capital accumulation, labor is evaluated as a fixed value. Therefore, the model is insufficient to provide information about the substitution of capital and labor (Yılmaz & Akıncı, 2012). The second important criticism is that technological progress is not included in the model. Under the assumption of no technological progress, the model oversimplifies economic growth sources: capital and savings (Nasrudin, 2022b).

3.4 Endogenous Growth Approach and Technological Progress

Because technological progress is exogenous in the neoclassical growth model, it would appear that the model does not adequately explain the most influential factor influencing the growth rate. Numerous researchers have attempted to "endogenize" the category of technological changes because of economic and other processes resulting from this circumstance. In the 1980s, theoretical approaches that attempted to depart from neoclassical orthodoxy to explain the origin of technological change emerged. Although this group of explanations is extremely diverse, they can be categorized as endogenous growth theories (Greenhalgh & Rogers, 2010)

The origins of endogenous growth models can be traced back to the work of economists such as Smith (1776), Marx (1867), Schumpeter (1926), and Arrow (1962). Smith's concepts of specialization and division of labor support technological development; Marx believed that new products and production processes would improve competition, which was the case with technological development. Schumpeter, greatly influenced by Marx, emphasized technology with concepts such as innovation, invention, and creative destruction. Arrow's defense is that, with the concept of learning by doing, costs will decrease over time for some sectors, quality will increase, and production will accelerate. Thus, new products can be introduced, emphasizing how much priority should be given to technological development (Arrow, 1962)

The concept of endogenous growth, which started especially with the studies of Romer (1986) and Lucas (1988) and continued to be developed in the 1990s, is, in its simplest sense, the search for the elements of economic growth within the system (Berber, 2006). The dominant viewpoint of endogenous growth theories is that knowledge, which serves as a catalyst for technological progress, is a fundamental factor in the economic growth of nations. These theories have established frameworks in which the primary determinants of economic growth encompass technology spillovers, R&D activities, and the transfer of technology across international borders.

The central proposition of endogenous growth theory involves the removal of the assumption of decreasing returns on factors of production. This enables an environment conducive to unrestricted development in productivity per worker. Under the assumption being considered, it is not implied by endogenous growth models that convergence is likely to occur or that the steady-state growth equilibrium will be reached. This is because endogenous variables are determined within the economic model, whereas exogenous variables are viewed as given in the economic model analysis. (Cvetanović et al. 2011).

A substantial multitude of divisions exist within the realm of endogenous growth models. One of the classifications pertains to the categorization of these models into three distinct groups: a) the AK models, b) endogenous models that are founded on externalities, and c) models that are based on R&D activities. Given this thesis subject and objective, it is certain that the endogenous growth models based on externalities in the form of technological spillover (Romer, 1986) and growth models based on activities of applied R&D (Romer, 1990; Aghion, Howitt, 1992; Grossman, Helpman, 1991) are the most important in light of the subject and purpose of the research (Sredojević, Cvetanović, & Bošković, 2016).

A) AK Models

The neoclassical model recognizes the presence of diminishing returns to capital accumulation, which serves as a significant factor in constraining economic growth. In an economy where technology and labor employment remain constant, the impact of capital accumulation on aggregate production is subject to diminishing returns. Nevertheless, there exists a category of models whereby one of these other determinants is postulated to increase automatically in direct proportion to capital. In these models, the rise of this alternative determinant offsets the impact of diminishing returns, so enabling output to expand in proportion to capital.

One of these models and the first endogenous growth theory model, known as the AK model, was based on learning by doing. The AK model, alternatively referred to as the Arrow model of economic growth, is employed to elucidate the economic transformations that occur due to advancements in innovation and technology (Corporate Finance Institute, n.d.). The Arrow model incorporates the "learning by doing" approach to elucidate how self-practice and invention contribute to enhanced productivity and the development of human capital (S. Kumar, n.d.). The reason for this phenomenon lies in the fact that the process of learning via practical experience results in a reduction in the amount of labor needed to produce a single unit of output; therefore, the diminishing returns to physical capital are offset by the accumulation of human capital.

Arrow (1962) proposed that technological progress is an unforeseen consequence of the production of new capital products. The AK model posits that when individuals accumulate capital, the process of learning by doing leads to technical advancements that typically result in an increase in the marginal product of capital. This counters the natural tendency for the marginal product to decline without technological progress. The production function is represented by the equation Y = AK, where Y represents the output, A denotes a constant, which is the level of technology, and K represents the capital input, which includes both physical and human capital. In this model, the marginal product of capital is equivalent to the constant A, and, thanks to the constant marginal product of capital, the economy grows at a constant rate (Aghion & Howitt, 2008).

B) Models Based on Externalities

These types of endogenous growth models suggest that positive externalities associated with capital accumulation (in a broader sense) result in constant or even increasing returns of the accumulable factor (Romer, 1986, 1987). Positive externalities invalidate the neoclassical model's assumption of diminishing returns to capital, making permanent increases in output growth rate conceivable (Nowak-Lehmann, 2000).

In their respective works, Romer (1986), Lucas (1988), and Rebelo (1991) have excluded technological change as a factor in economic growth. Instead, they propose that growth in these models is primarily driven by continuous investment in capital, which generates positive externalities for the economy and mitigates the diminishing returns associated with capital accumulation (R. J. Barro & Sala-i-Martin, 2004).

It is believed that endogenous growth theories originated with the publication of Romer's model in 1986. Romer (1986) developed a model that explores the concept of endogenous growth resulting from knowledge externalities. According to this model, the productivity of a particular firm is positively influenced by the average knowledge stock of other firms. In this model, knowledge acquisition is a by-product of a company's decision to invest in physical capital. Capital accumulation indirectly influences the company's knowledge base due to the process of learning by doing. As a result of the consequences of knowledge spread, also known as the spillover effect, other companies are also able to receive benefits; hence, information continues to possess the qualities of a public good. The increased profits in these enterprises are the direct outcome of knowledge spillovers to other businesses in the form of positive technical externalities. (Sredojević et al., 2016).

According to Romer, it is the spillovers from a company's research efforts that contribute to the development of new knowledge by other companies. In other words, a company's new research technology immediately impacts the entire economy. According to his model, the ultimate determinant of long-term development, which is determined by investments in research technology, is new knowledge (Kumar, n.d.).

Romer emphasizes the positive externalities of physical investment and knowledge, while Lucas (1988) emphasizes the positive externalities of human capital accumulation (Nowak-Lehmann, 2000). Lucas posits that the allocation of resources towards education results in the generation of human capital, a pivotal factor in the process of economic progress. He distinguishes between the internal consequences of human capital, wherein individual workers who receive training become more productive, and the external consequences that extend beyond the person and enhance the productivity of capital and other workers within the economy. The spillover effect that leads to a growth in technology levels is mostly driven by investment in human capital, as opposed to physical capital (Kumar, n.d.).

C) Models based on R&D Activities

Within the new endogenous growth theories, three approaches emerge clearly, in which the main factor in ensuring the continuity of growth is thought to originate from the R&D sector. Drawing upon the seminal contributions of Schumpeter (1961), Romer's (1990) model, Grossman and Helpman's model (1991), and the model of Aghion and Howitt (1992) are the fundamental works of this approach (Ateş, 1998).

In these models, the ability of the economy to have a continuous growth effect in the long term is closely related to the number of researchers (scientists, engineers, technical personnel) that the economy transfers to the R&D sector.

The endogenous growth models within this framework suggest the presence of monopolistic structures, the concentration of power, and the coexistence of a distinct research sector within the economy. This research sector plays a distinctive role in providing technology to other sectors. Manufacturers acquire the legal entitlement to utilize the new technology by the act of purchasing it. The price charged is greater than the marginal cost of production in order to generate sufficient revenue to cover the costs incurred as a result of a substantial initial investment in developing innovative technological solutions. In this regard, innovation project investments do not exhibit diminishing returns. Therefore, there is no reduction in the productivity of new investment in innovative activity, a condition of sustainable economic growth. The growth rate in these model presentations is contingent upon several factors, including the allocation of funding towards research and development endeavors, the extent to which new technology may be privately utilized (monopoly power), and the temporal perspective of investors (Sredojević et al., 2016).

In Romer's paradigm, which is based on R&D, growth is driven by technological progress resulting from businesses' profit-maximizing investment decisions (Romer, 1990). Romer prioritizes technology over other products because it is non-competitive and only partially exclusive. A product's degree of competitiveness is determined solely by its technological characteristics (Sredojević et al., 2016).

The Romer model is based on R&D activities, human capital employed in the R&D sector, and production techniques produced in the R&D sector. According to Romer, while advances in R&D activities reveal new designs, this information will cause a spillover effect as other companies in the sector use it. With this spillover effect, a greater impact on overall economic growth can be achieved by increasing knowledge acquisition and stock (Taban, 2011). Thanks to the existence of intellectual property rights protected by legal regulations, information will not only remain in the public domain status but will also pave the way for the promotion of inventions. In addition, the partial availability of information to the public will trigger an increase in R&D activities for companies and individuals, thus increasing revenues.

Grossman and Helpman's studies dated 1989, 1990, and 1991 form the basis for technological innovation, innovation, and R&D-based growth approach. They combine ideas from new growth theory and insights from new trade theory to analyze the relationships between trade, innovation, and growth. Grossman and Helpman focused on how international exchanges of goods, services, and ideas affect the incentives and diffusion of knowledge.

Based on technological innovations, Grossman and Helpman’s growth model focuses on explaining growth with the concepts of foreign trade and openness. Grossman and Helpman see international trade as a means of international knowledge diffusion. Accordingly, providing technology transfers from developed countries by increasing the openness of less developed countries, which cannot allocate sufficient resources to R&D investments, will pave the way for them not to be completely away from technology and thus to be able to implement the technological process they need in their countries. For this to happen, these countries need to support investments in R&D with incentives and subsidies during the policy-making process. International knowledge spillovers tend to accelerate growth in all nations, as the expense of innovation in each nation decreases as advancements are achieved in other nations (Grossman & Helpman, 1991).

Furthermore, Grossman and Helpman also explore the role of comparative advantage in determining the trade patterns and growth performance of different countries. According to them, the R&D sector, supported by technology transfers brought about by openness to the outside world and trade, will also become the driving force of growth by providing comparative advantage to the country's economy. If technological spillovers are global, innovative firms will have access to a common pool of knowledge. Thus, a country well equipped with human capital will specialize in R&D and gain a comparative advantage in this field (Sena & Fontenele, 2004). Countries, regions, or cities that are the first to develop a particular industry gaining a comparative advantage through knowledge diffusion, can benefit from increasing returns, leading to a permanent pattern of economic activity (Cortright, 2001).

Aghion and Howitt's (1992,1998) model has a Schumpeterian approach that predicts higher output growth for societies with high R&D intensity. This framework emphasizes the role of internal R&D and patenting activities on productivity and economic growth. They can be listed from R&D intensity to patenting, from patenting to productivity, and from productivity increase to output growth (Zachariadis, 2000).

Aghion and Howitt (1992) introduced a growth model that revolved around creative destruction and emphasized the importance of innovation in improving product quality. They developed a different model of innovation, vertical innovation, which is the main engine of economic growth. The basis lies in the idea that innovation creates new products and technologies and destroys old ones by making them unnecessary (Maré, 2004).

Another issue brought by this model reflects that as there is less competition in the production of intermediate goods, it is more difficult to imitate the inventions in that economy, meaning that the protection of intellectual property rights can be applied more effectively (Ünsal, 2007). As a result of the protection of patent law, the firm can act as a monopolist to market a new product. The potential for monopoly drives businesses to innovate and create better products to take the position of the long-standing monopolist in the market. The more tightly intellectual property rights are protected by patents, the more effective this will be on economic growth (Çetin, 2013).

CHAPTER IV

REVIEW OF LITERATURE ON INTERNATIONAL TECHNOLOGY DIFFUSION

Technology diffusion refers to the spread of knowledge resulting from R&D operations that cannot be protected as intellectual property (Kaiser, 2002). Spillovers, in this context, pertain to knowledge that is exclusive and not accessible elsewhere, thereby generating value for other participants in the economy. Technology or knowledge may diffuse across specific units (firm, industry, region, etc.) at a national level or at an international level.

As suggested by endogenous growth theory, economically motivated R&D activities are the fundamental source of sustained economic growth, and the role of technology is significant in elucidating the disparities in income levels among nations is possible because of the diffusion of knowledge from these innovative activities across countries. This is why technological diffusion is crucial for less developed countries.

Since international technology diffusion is an essential triggering factor in the phase of economic growth through externalities mostly based on the knowledge from R&D and other innovative activities, there is an enormous literature to detect how this diffusion can emerge and which channels help to trigger this process across countries.

Furthermore, it is not enough to obtain new technology; it is crucial to possess the capability to deploy the obtained technology effectively, particularly for developing nations. Without this expertise, a nation cannot reap the advantages of new technology and advance its technological development. Countries' inventiveness in adopting diffused technologies and deriving benefits from them varies depending on, for example, their trade pattern, degree of openness, the set of domestic institutions, or geographic localization.

All in all, because one of the main aims of this paper is to analyze the relative effectiveness of technology diffusion channels across developing countries, the first aim of this chapter is to review the studies in the literature that focus on the effect of international technology diffusion on economic and productivity growth. The second aim is to present the studies showing the sources of heterogeneity in the technology spillovers gains.

4.1 Studies Related to International Technology Diffusion Channels

What is the extent of cross-border transmission of technological knowledge, and how are these knowledge transfers facilitated? These problems have garnered more attention in the past decade, as prominent experts in international economics have dedicated significant research efforts to the extensive subject of knowledge spillovers. Many research has utilized regression methods to examine the extent of international technology spillovers. These studies have analysed the channels or mechanisms in which technology spillovers occur to determine if foreign technological activity can impact domestic productivity.

Thanks to the influential study conducted by Grilliches in 1979, two clear concepts of R&D spillovers have been firmly established: Rent spillovers and knowledge spillovers. Unlike rent spillovers, which are entirely derived from economic transactions, genuine knowledge spillovers may not necessarily require economic activities. Due to this distinction, international knowledge spillovers channels are categorized as the direct (disembodied) and indirect (embodied) channels. In this section, studies examining these channels will be presented.

4.1.1 International Trade and International Technology Diffusion

With the world's increasing globalization, there has been a growing emphasis on examining the impact of trade integration on economic growth or productivity and understanding the underlying mechanisms that drive this relationship. Typically, more developed nations possess a competitive edge in manufacturing capital or intermediate goods that need a high level of expertise, as they have a greater amount of intellectual knowledge capital. Based on the Eurostat (2020) classification, OECD nations accounted for over half (roughly 50.6%) of global high-tech product exports in 2019 (World Bank, 2022). Therefore, developing nations have the potential to benefit significantly by engaging in trade integration with countries that possess a wealth of expertise.

In this regard, it is frequently argued that global supply chains can serve as a potential channel for international knowledge spillovers. A significant body of literature asserts that trade promotes knowledge flows and technology transfers among trading partners. The fundamental premise is that products embody technological know-how; consequently, countries can acquire foreign knowledge through trade.

Whether international R&D spillovers are trade-related, and the extent to which foreign knowledge's impact on domestic TFP depends on international trade are still debated. In this part, the most discussed knowledge-embodied (indirect) international R&D spillovers channel trade is analyzed through the studies in the literature. The literature mainly focuses on import channel rather than export channel. However, in this section, export-related works are also considered.

A. Import

Imports can impact economic performance or productivity in three ways. Firstly, the utilization of higher-quality imported capital goods leads to an improvement in the productivity of the final goods production by including a wider range of inputs. Furthermore, introducing imported new inputs is expected to significantly improve learning activities by capitalizing on the disparities between pre-existing technology and newly acquired imports. Moreover, although local competitors and trading partners may attempt to replicate imported innovations, the growing competition driven by technological progress encourages both exporter and importer firms to focus on expanding their presence in markets through new technologies (Teixeira & Fortuna, 2010).

From the benefits of import listed above, it can be clearly seen that, imports of goods serve as a channel for the diffusion of knowledge across borders. That is, the results of innovative activities in a country influence other countries' productivity mainly via imported goods because imports can serve as a means to acquire knowledge about products, encouraging imitation or the creation of competitive products. There is extensive literature about import-embodied channel of international knowledge spillovers; some of these studies will be presented in this section.

A macro-level empirical investigation into such knowledge spillovers between countries was first attempted by Coe and Helpman (1995) (hereafter CH) with the panel data of 21 OECD countries and Israel from 1971–1990. They construct a regression to see the effects of domestic and foreign R&D capital stocks, which is a measure of knowledge or innovative activity, on TFP. To assess the import-embodied knowledge spillovers effect, they compute the weighted sum of trading partners' foreign R&D capital stocks where the weights are the bilateral import shares between countries (import composition effect). Furthermore, to allow more heterogeneity between countries and to observe the productivity gains from trade clearly, they add the ratio of import to GDP as a measure of a country's trade openness for the coefficient of foreign R&D stocks (import share effect). The authors find that international knowledge spillovers through trade have had a substantial role in the increase of TFP in the OECD countries and that the magnitude of the benefit grows in proportion to the domestic economy's openness to international trade.

Wolfgang Keller, who has many works related to international R&D spillovers, focuses on the robustness of CH’s results in his Keller (1998) study. He examines whether knowledge or technology can spillover through international trade. Therefore, he focuses on CH’s foreign R&D stocks construction, which is a weighted sum of the R&D stocks of the country’s trading partners, and the weights are the bilateral import shares. Shortly, he concentrates on the import composition of the countries in the CH dataset. Through the Monte-Carlo experiments, Keller (1998) creates random bilateral import shares between these countries and estimates modified CH regression based on counterfactual international trade patterns. According to the results, import-embodied foreign R&D capital stocks with randomly created bilateral trade patterns also have a positive and significant effect on TFP, which is even higher than the CH's original regression with true bilateral trade patterns. He states that these results raise some doubts on the assertion that international R&D spillovers are trade-related; however, to reach a certain result, trade-unrelated channels of international R&D spillovers should also be included in the regression.

Lichtenberg and Van Pottelsberghe De La Potterie (1998) (LP hereafter) also criticize the CH's work for two issues. The first issue is CH's weighting scheme, which they used to compute the spillovers from foreign R&D capital stocks, which is the sum of bilateral import share-weighted trading partners' cumulative R&D stocks. LP criticizes this weighting scheme because of the potential aggregation bias. They state that when trading partners theoretically merge, a country's foreign R&D stock rises even though the domestic R&D stocks and trade flows between them stay the same. Then, instead of using bilateral import share, LP proposes an alternative weighting scheme: the ratio of bilateral import to importer country's GDP. The second issue is CH's indexation to show how a country's trade openness affects the benefit from international R&D spillovers. After dealing with aggregation and indexation bias issues, LP estimates the modified CH equation and finds that more open economies are more likely to benefit from international R&D spillovers.

There is another similar work with CH in literature, which was conducted by Frantzen (1998). He also analyses the long-run effects of domestic and foreign R&D efforts on TFP for panel data of 21 OECD countries from 1965 to 1991. However, Frantzen (1998) criticizes CH's work for not interpreting their OLS estimation results within a panel cointegration framework (whether those estimates are statistically significant) even though they conduct cointegration tests. For this reason, to increase the robustness of estimation results, he uses both OLS and dynamic OLS (DOLS) estimation procedures, and he also estimates error correction mechanism (ECM) equations corresponding to the respective cointegration equations in addition to cointegration equation to assess causality relation between TFP and R&D variables.

Like CH, he thinks that since most of the innovation creation or R&D efforts happen in developed economies, their TFP might be affected by domestic R&D more than in the case of the smaller economies. Therefore, he also uses a dummy variable for domestic R&D stocks that takes the value of 1 for the seven largest economies (G7). He reaches similar results with CH and shows that domestic and foreign R&D efforts have a positive and significant effect on TFP; however, the effect of international technology spillovers is even more substantial. Moreover, in more developed economies, the effect of domestic R&D is more significant. Furthermore, causality analysis reveals that the causality runs from R&D to productivity rather than vice versa.

A response to Keller (1998) comes from the work of Coe and Hoffmaister (1999). They raise some doubts about the robustness of Keller's (1998) results, which claim that randomly created bilateral import shares perform better at the impact of import-related R&D spillovers on TFP than true bilateral import shares. Therefore, to clear up these doubts, they examine closer Keller (1998)'s way of creating random trade patterns. Finally, they show that the probability distribution of Keller's "random" shares does indeed cluster tightly around the inverse of the number of trade partners. This means that Keller (1998)'s random bilateral import shares are not random; they are just simple averages of the R&D capital stocks of trading partners with a random error. Then, they create three alternative random bilateral import shares that do not display the same property of Keller's random share. After estimating the expanded version of CH regression with true bilateral import shares, Keller's simple average shares, and three random shares, the results claim that foreign R&D capital stocks weighted with bilateral import shares or simple average shares have positive and significant spillovers effect on TFP whereas there is no clear relation between three randomly created import shares weighted foreign R&D stocks and TPF. This result supports the idea that import is a channel for international knowledge spillovers.

Another criticism of CH's work is from Kao, Chiang, and Chen (1999). They think CH's results are unreliable because their work lacks a strong econometric base. Although CH did the necessary tests to prove a long-run relation between TFP and domestic and foreign R&D stocks (cointegration), they failed to interpret their estimation results within a cointegration framework. According to Kao et al. (1999), CH missed two things about their cointegrating regression. Firstly, they did not consider the asymptotic distribution of the t-ratios of estimates, which means they did not consider whether those estimates were statistically significant. Secondly, they use the OLS estimation procedure, which is unsuitable for finite samples, and can lead to estimation bias, which may suspect estimates are correctly signed. To fix these issues, Kao et al. (1999) benefit from Kao and Chiang (1997)'s work, and they use different estimation techniques to reassess the results of CH. They reestimate the CH's regression with OLS with bias correction, Fully-Modified (FM), and DOLS estimations. They find that all estimation methods give a positive relation between domestic R&D stocks and TFP; moreover, this relation is stronger in G7 countries compared to smaller countries. Also, bias-corrected OLS and FM give a positive linkage between foreign R&D and TFP, whereas DOLS suggests that the impact of foreign R&D stocks on TFP is insignificant. Because Kao and Chiang (1997) claim that the DOLS estimator is more powerful than OLS or FM estimators in estimating cointegrated panel regressions, Kao et al. (1999) reject CH's hypothesis that trade is a channel of international R&D spillovers.

Similar work to Kao et al. (1999) is conducted by (Edmond, 2001), which claims that CH could not present convincing evidence of the panel cointegration necessary to validate their chosen estimation approach. He also defends that more heterogeneity between countries should be allowed in CH's regression, then, he adds the fraction of imports in GDP, which shows the trade openness, as a new regressor. By using Pedroni (1997, 1998)'s panel cointegration tests and different estimation methods for cointegrated panel data, like group mean estimation techniques in addition to the pooled mean group techniques, he estimates the modified CH regression and concludes that the effect of import-embodied international R&D spillovers on TFP becomes unsteady and weaker with new estimation methods, which cast a doubt about the results of CH.

Lee (2005b) also examines the relation between international R&D spillovers via intermediate goods import and TFP. In this paper, by referring to the other studies that challenge the results of CH, Lee considers CH's regression with new panel dataset from 17 countries for the extended period of 1971-2000. According to Lee (2005b), negative results from the studies that criticize the CH's work, like Keller (1998), Kao et al (1999), and Edmond (2001) cannot also be reliable because these studies all used the dataset of CH and especially old databases. Furthermore, he states that unreliable results of CH mainly arise from the limited cointegration tests of panel data and lack of alternative estimation methods applied to the cointegrated regression rather than OLS in small samples (to get valid t-statistics). To solve these problems, Lee (2005b) uses alternative estimation method; group mean panel FMOLS, suggested by Pedroni (2000, 2001), which shows better performance under relatively small samples than within dimension panel panel FMOLS and DOLS estimates used by Kao et al (1999). He also uses alternative different panel cointegration tests suggested by Pedroni (1999). With this new dataset, he estimates the CH's regression with OLS, within dimension FMOLS and DOLS used by Kao et al. (1999), and group mean FMOLS. All estimation results give a positive and significant relationship between TFP and international R&D spillovers embodied in imported intermediate goods, which contradicts the results of Keller (1998), Kao et al. (1999), and Edmond (2001).

Lumenga-Neso, Olarreaga, and Schiff (2005) carry out a study to reconsider the contradictory results of the CH and Keller (1998). However, to properly analyze whether trade is a channel for R&D spillovers, they also consider the possible spillovers from indirect trade. They think that when County A imports from Country B, country A's productivity is not only affected by County B's domestic R&D stocks, it is also affected by Country B's trading partners' domestic stock of R&D. Then, to see the indirect trade-related R&D spillovers effect, they construct a variable that measures this effect from indirect foreign knowledge stocks. Furthermore, they use CH's regression with small changes for 114 countries, including non-OECD countries, to assess the indirect spillovers through the import channel. According to the results, indirect trade-related R&D spillovers are at least as significant as direct R&D spillovers for TFP; moreover, due to the existence of indirect effects, bilateral trade patterns are comparatively less influential in determining the level of knowledge spillovers through trade. All in all, these results confirm that trade is a channel for international knowledge spillovers.

Bitzer and Geishecker (2006) bring a new perspective to the studies related to the effect of trade-embodied knowledge spillovers on TFP. They state that the other studies did not pay attention to the decomposition of trade channel. Analyzing the different types of trade as a channel for knowledge spillovers is crucial for the balance between knowledge spillovers and competition effects of trade. This means that potential spillovers can be offset by competition effects that significantly reduce the scale of the scope of domestic production, resulting in productivity losses. Therefore, for this purpose, they decompose trade channels and assess their impact on output productivity for industry-level data of 17 OECD countries between 1973 and 2000. Foreign R&D capital stocks are weighted with three different import shares for decomposition. The first is foreign R&D capital stocks weighted with overall manufacturing imports to see the aggregated level effect of trade-related spillovers. The second one is the foreign R&D capital stock weighted with sectoral imports in the manufacturing industry to capture the effect of knowledge diffusion through intra-industry impact. The third one is R&D capital stocks weighted with intra-industry imports of intermediate goods to see the effect of international outsourcing as a knowledge spillovers channel. These three trade channels enter the regression with domestic R&D stocks and factors of production to see their interaction with manufacturing sector output. The estimation results show that all manufacturing imports significantly and positively affect productivity, proving that import is a channel for knowledge spillovers. On the other hand, intra-industry imports negatively affect productivity because the competition effect related to imported final goods offsets the positive spillovers effects. Contrary to the overall intra-industry imports, intra-industry imports of intermediate products are a significant channel for knowledge spillovers.

To investigate the roots of the connection between international trade-related knowledge spillovers and TFP growth, Madsen (2007) extends the work of CH for the 135 years of data for 16 OECD countries. He makes some differences compared to other similar studies in the literature. The first difference is that he uses patent data as a measure of knowledge or innovative activity instead of using R&D data. Although R&D stock is a great indicator of knowledge, he prefers patent data because R&D data was not available across OECD countries until the 1960s; therefore, the effect of import-embodied knowledge spillovers on TFP can be assessed unambivalently using patent data. The second difference in this paper is constructing a weighting scheme of foreign knowledge stocks. He states that because the knowledge spillovers through imports mostly occur via the imports of technologically advanced goods, he weights the trading partners' patent stock with a bilateral import share of high technological products. The estimation results of this study show that there is a long-term and robust relationship between import-embodied knowledge spillovers and TFP growth; moreover, one notable characteristic of the estimates is the close resemblance of the estimated elasticities of foreign and domestic knowledge to those found in existing literature which show that estimates are not substantially influenced by the choice of using patents or R&D as indicators of innovative activity.

Lee (2009) also analyses the international knowledge spillovers through the import of intermediate goods, but he only focuses on the imports of information technology (IT) commodities and non-IT commodities in the manufacturing sector of 17 OECD countries between 1981-2000. He states that one important limitation of the CH and the following research is the omission of considering the composition of intermediary commodities moved between countries. If the imports of intermediate goods from technologically advanced nations mostly consist of a small number of knowledge-intensive commodities, then even a significant volume of these imports will not result in a substantial level of knowledge spillovers. (G. Lee, 2009). He uses two different foreign R&D stocks for IT and non-IT commodities with LP's (1998) import weighting structure. He also adds Jaffe's (1988) technology proximity as a measure (or weight) of direct R&D spillovers because he thinks the estimated effects of foreign knowledge spillovers via imports may be deceptive without adding direct channels of international R&D spillovers. By using OLS and GM-FMOLS estimation techniques, Lee finds that IT imports have significant positive effects on productivity through import-embodied R&D spillovers, whereas non-IT imports have a negative effect on productivity. Also, direct R&D spillovers estimated using technology proximity measures are statistically insignificant.

Weina, Xin, Botang, and Ni (2014)'s work is one of the examples of a country specific investigation of the relationship between trade and R&D spillovers. They examine whether technology spillovers arising from international trade would positively promote China’s technological progress and what kind of trade gains the most spillovers effect to China. To investigate these questions, they use CH’s regression, but with a difference: they use the ratio of imports to GDP as weights to measure foreign R&D stock (LP method). They choose OECD countries with more international trade with China between 1995 and 2010. Their results indicate that R&D spillovers resulting from trade affect China's TFP considerably. However, in some countries, international trade does not produce technology overflows significantly. This effect varies in countries. According to Weina et al., the main reason for this is the difference between the composition of imported goods from China’s trading partners. For example, the United States affects China’s TFP more than Australia because China mainly imports technology equipment and electronic communication products from the United States, whereas it imports natural resources, minerals, energy products, and agricultural products from Australia.

Hall (2019) focuses on how technological progress affects income inequality with trade liberalization. His work mainly aims to assess the effect of technological progress on income inequality, but special attention is given to the technological progress that spillovers through trade. World Bank (WB) provides numerous measures of technological change for a vast array of developing nations. For example, data for high-tech exports, R&D expenditures as a percentage of GDP, capital formation, information and communication technology (ICT) imports, and the proportion of R&D researchers to the population are considered. However, according to him, these variables are consistent with previously employed measures of technological change, but they are restricted from the late 1990s to the present, thereby limiting any analysis to this period, and they cannot properly measure the technology that diffuses with trade. Then, he develops a new measure of technological advancement by estimating the high-skill content of imports using bilateral trade data at the industry level. He uses the gravity model[13] to compute the high-skill content of imports between countries. In addition to this new measure, he includes some other measures of technological change

[13] Gravity models predict trade volumes between countries based on each country's size, geographical distance, and other exogenous variables, such as a shared border, a common language, or a history of colonization (Hall, 2019)

with variables that affect the income inequality in regression. The results claim that the high-skill technologies embodied in imports have a positive and significant effect on income inequality in the importer country.

In this part, the literature is used to analyze the most discussed knowledge-embodied international R&D spillovers channel trade by mostly emphasizing import. Since the effect of trade-related knowledge spillovers is still debatable, the other channels of international knowledge spillovers must be included in the discussion to understand the complete effect of this channel, especially for econometrics. Hence, the next two chapters will analyze other channels through the studies in the literature.

B. Export

Export is a clearly established factor that influences economic and productivity growth. Exporting increases productivity by generating several advantages, including improved resource utilization, increased capacity utilization, and realizing economies of scale linked to large global markets. Sectors that engage in exporting typically demonstrate higher levels of productivity compared to sectors that focus on domestic market output.

Furthermore, exporting can potentially boost productivity by providing a channel for knowledge spillovers. For example, when domestic products are exported, foreign buyers may propose methods to enhance the production procedures (Grossman and Helpman, 1991). To successfully export items, it is crucial for the manufacturer to have a thorough understanding of the demands of overseas buyers, which includes their special criteria regarding product specifications and quality. Utilizing the insights gained from analyzing buyers' preferences can be leveraged to improve firms' own efficiency. Therefore, participating in export markets allows firms to access international best practices, gain knowledge, and increase productivity. Because the necessary information to enhance basic capabilities has been obtained from export buyers, who have freely shared product designs and offered technical assistance to improve process technology as part of their sourcing activities, a portion of the effectiveness of export-oriented growth can be ascribed to the external benefits arising from the act of exporting (Pietrucha and Żelazny, 2020b).

Nevertheless, the role of export as a means of technology or knowledge diffusion is not as intuitively apparent as the role of import or FDI. This channel has received less attention in previous empirical investigations. During the 1990s and 2000s, few studies examined the diffusion of knowledge through exports. However, most of these studies failed to establish a definitive link between knowledge spillovers and exports. Furthermore, the primary objective of these studies was to investigate the learning by exporting, which is the increase in productivity that firms experience after they begin exporting, achieved through enhancements in quality, upgrades in technology, development of new products, imitation of superior marketing techniques, or improvement in management skills.

Furthermore, because international knowledge spillovers occur simultaneously through multiple channels, the existing studies that concentrate on the role of export as a channel of knowledge spillovers largely include the other channels but do not examine the role of export directly and in detail. This part will examine some studies related to the relationship between international knowledge spillovers and exports.

Clerides, Lach, and Tybout (1998) state that empirical studies frequently demonstrate that exporting firms exhibit greater efficiency than their domestically oriented equivalents; however, these studies did not examine the causal relationship between exporting and productivity. For this reason, Clerides et al. aim to ascertain the direction of causality and establish whether there is any empirical evidence supporting the notion that firms enhance their productivity by engaging in export activity. Their main aim is to detect the learning by doing or learning by exporting process because they believe the firms’ productivity is enhanced after entering export markets. Additionally, to evaluate the argument favoring active export promotion, they examine whether exporters provide positive externalities or spillovers to other firms by serving as a channel for knowledge gained through trade. Their investigation for identifying learning effects from export is rooted in a straightforward concept. If the act of exporting does actually result in increased efficiency, then firms who initiate exporting should subsequently demonstrate a modification in the random process that regulates their productivity growth; therefore, their production trajectories must enhance to some extent once firms start operating in international markets. Likewise, if the existence of exporters creates spillovers that extend beyond their own operations, non-exporters in the impacted industry or area should experience alterations in their cost structure as the number of exporters fluctuates. The results of this study for Colombian, Mexican, and Moroccan firms show that firms with relatively high efficiency levels tend to engage in exporting; however, in most industries, a firm's costs are not influenced by its prior exporting activity. The well-documented correlation between exporting and productivity can be attributed to the fact that more efficient firms tend to choose to enter the export market. Additionally, the results show certain indicators of favorable knowledge spillovers from exporting firms.

Funk (2001) re-examines the relationship between international trade and knowledge spillovers by emphasizing the two contradicts works of CH (1995) and Keller (1998). However, contrary to these two papers, Funk (2001) takes into account the export channel in addition to the import channel to investigate how countries benefit from their export relationship through knowledge spillovers. Funk thinks that knowledge spillovers may be prompted by customers' suggestions regarding prospective improvements in productivity; furthermore, by raising the cost of not improving or by boosting the incentives for achieving success, the heightened competitive forces of the global marketplace may motivate companies to seek out ways to improve efficiency actively. For these reasons, export can be an alternative transmission mechanism for international R&D spillovers. He uses the modified CH (1995) model for the investigation by adding foreign capital stocks calculated as the weighted average of trading partners' R&D stocks, where the weights are bilateral export shares. According to the paper's results, there is strong evidence indicating that export has a strong effect on productivity through spillovers; on the other hand, the results do not support a relationship between import-embodied knowledge spillovers and productivity. According to Funk, the reason behind this result is the influence of imported intermediate goods is static and only has a one-time effect unless the knowledge included in imports is retrieved and used to boost productivity while the information gains from export partnership can be utilized further through learning by doing.

Moreover, the competitive dynamics of the global market can impact the capacity to capitalize on international spillover effects. Market dynamics may compel exporters to obtain and assimilate foreign technologies rapidly. Technologically superior overseas competitors may force importers to exit the research field or cease operations altogether.

Wei and Liu (2006) study how firms' productivity is affected by other firms' export activity through knowledge spillovers; however, rather than only focusing on the spillovers from export, they also include the R&D spillovers and FDI spillovers. This firm-level study considers the Chinese manufacturing sector between 1998 and 2001. They consider the impact of both domestic and foreign knowledge spillovers on Chinese indigenous firms' productivity. These firms' productivity depends on their own export and R&D activity, the knowledge spillovers from other firms' R&D and export activities, and FDI spillovers. For the investigation, Wei and Liu emphasize the geographical scale of productivity spillovers and divide China into three macro areas to assess local and national knowledge spillovers. Moreover, they also look at the differentiated effects of intra- and inter-industry knowledge spillovers for these three channels. The results show negative export spillovers between firms in the same industry, both within and between regions. Additionally, there are positive export spillovers between firms in different industries within regions. According to Wei and Liu, the incentives offered by the Chinese government could intensify the rivalry for exports among foreign-invested and domestic Chinese firms in the same industry, resulting in an adverse intra-industry spillovers effect. Like in export, there are positive inter-industry spillovers from R&D and positive intra- and inter-industry knowledge spillovers from FDI within regions only.

Pietrucha and Żelazny (2020b) assert that most research on international knowledge spillovers literature has concentrated on the imports and FDI channels, whereas other alternative channels have not been thoroughly investigated. They also state that import, export, and FDI are the main channels of international spillovers; however, export as a potential channel of external TFP effects has been incorporated into studies to a much lesser degree. These three channels should be considered together to assess which channels are utilized for technology spillovers and their relative significance. In their econometric model, Pietrucha and Zelazny (2019) calculate the spillovers based on CH (1995), which is the sum of the weighted average of trading partners' R&D stocks where weights trading partners' share in total inflow of FDI, import or export; however, rather than using foreign R&D stocks as an indicator for innovative activity, they use TFP of trading partners of a country. In the model, the TFP of a country, as a dependent variable, is affected by import-export levels, capital stocks, domestic R&D expenditures, patent applications, human capital, and some country-specific institutional variables like political stability, in addition to the spillovers from these three channels. According to the estimation results for 41 countries between 1995 and 2015, the export channel is the most significant among the analyzed countries.

4.1.2 Foreign Direct Investment (FDI) and International Technology Diffusion

The flow of goods is not the only channel through which knowledge can spread internationally. In addition to trade, knowledge can also spillovers internationally through FDI.

Spillovers from FDI may arise when local enterprises boost their efficiency by observing or employing individuals trained by foreign affiliates operating in the local market and replicating their innovations. Another sort of spillover happens when a multinational presence raises rivalry in the host country's market, forcing local enterprises to use their existing resources better to seek out new technology (Blomström & Kokko, 1998).

Compared to trade, FDI as a knowledge-embodied channel is a more controversial subject in the literature. In this section, some of the studies related to the role of FDI in international knowledge spillovers will be analyzed.

Aitken and Harrison (1999) suggests that FDI in a country brings both positive and negative effects for domestic firms. The existence of multinational firms can be beneficial through experiencing their technological know-how, marketing, and managing skills and international networks or through experienced labor turnovers and upstream or downstream linkages with foreign firms. However, at the same time, the presence of foreign firms in domestic markets can create negative productivity effects through a "market-stealing" impact, which is when foreign firms take market share away from domestic firms, forcing domestic firms to produce less at higher costs. For these reasons, Aitken and Harrison (1999)'s aim is to examine the net effect of FDI on countries' productivity. They focus on two questions: one is whether foreign ownership in a plant (firm) increases the plant's productivity, and the other one is how the presence of foreign ownership in an industry affects domestic firms' productivity or whether there are any technology spillovers to domestic firms from foreign firms. For this investigation, they use nearly 4.000 Venezuelan manufacturing firms between 1976 and 1989. The results show that the productivity of firms receiving FDI is positively affected by foreign equity participation; however, increases in foreign equity participation negatively affect the productivity of domestic firms in the same industry, indicating negative spillovers from foreign firms. Taking these two balancing impacts into account together, the net impact of FDI is fairly small for domestic countries, and there is no evidence of positive technology spillovers from foreign firms to domestic firms.

Xu (2000) criticizes the studies in the literature looking for the existence of productivity gains from FDI through international technology spillovers for two aspects. The first aspect is the different FDI definitions of countries leads to poor quality of data, and this situation causes unreliable results related to FDI-induced spillovers. The second aspect is that earlier studies generally measure the spillovers from FDI through FDI as a share of the domestic country's GDP; however, this type of measurement takes all positive externalities of MNEs on productivity rather than distinguishing only the spillovers effect. Due to these drawbacks of earlier studies, Xu (2000) prefers the technology diffusion intensity of MNE affiliates rather than FDI shares to reflect the spillovers effect of MNEs properly. He considers the US manufacturing MNEs in 40 developed and least developed countries for the period of 1966-1994. For the econometric analyses, Xu (2000) uses the proportion of MNE affiliates' value added to the domestic country's GDP to capture the overall productivity impact of the existence of MNEs, and he uses the ratio of MNEs' spending on license fees and royalties to their value-added and to host country's GDP to capture the technology spillovers from MNEs. In addition, import as an additional channel and human capital as a proxy for absorptive capacity are also included in the model, where the dependent variable is the TPF growth rate. According to the results, Xu (2000) claims that there is a significant and positive spillovers effect on the productivity of developed countries from MNEs, whereas there is no strong evidence of technology diffusion from MNEs in least developed countries. Moreover, he asserts that the underlying reason why less developed countries cannot benefit from the technology spillovers from MNEs is the lack of well-educated human capital in these countries to attract and absorb foreign technology.

Branstetter (2000a) also examined the role of FDI as a channel of knowledge spillovers from the United States to Japan but was only able to do so indirectly by quantifying the comovement between the R&D expenditure of American firms and the patent granted to Japanese firms in the US (only outward FDI effect). In addition to examining the knowledge spillovers from FDI, an investigation is conducted to assess the degree of correlation between the export levels of Japanese firms to the US market and their enhanced ability to acquire knowledge spillovers from American firms. Firstly, he constructs a regression where innovative activity of Japanese firms is measured by number of patents granted in US, and it depends on i) their own R&D expenditures, ii) domestic knowledge spillovers, which is the weighted sum of external R&D performed by Japanese firms, iii) foreign knowledge spillovers, which is the sum of external R&D performed by related American firms, and iv) finally foreign knowledge spillovers related to the FDI of Japanese firms in the US (dummy variable). He also modifies this regression for the export channel by discriminating the Japanese firms according to their export intensity to the US market. This firm-level study consists of five manufacturing industries from 1986 to 89. The results indicate that Japanese firms with FDI in the US benefit more from the innovative activity of American firms (more patents granted to these firms in the US) than those without FDI. Also, Japanese firms with higher export levels to the US market gain more knowledge spillovers impact than firms without such significant export levels.

One of the studies relevant to FDI-related international knowledge spillovers is conducted by Van Pottelsberghe De La Porterie and Lichtenberg (2001) (PL henceforth). According to them, "… the extent to which country i benefits from country j's R&D investment depends on the degree of economic interaction between the countries, or of their exposure to one another." (Van Pottelsberghe De La Porterie & Lichtenberg, 2001). To assess the effect of FDI on TFP, they consider FDI as two different channels; one is foreign R&D capital stock embodied in inward FDI, which measures investment made in a country from another country. The second one is foreign R&D capital stock embodied in outward FDI, which measures investments made by domestic companies in a foreign economy (Ward, 2023). They use the modified version of their model in LP (1998) paper by adding inward and outward FDI-related spillovers channels with trade channel for 22 OECD countries over the period 1971-1990. The estimation results indicate that inward FDI does not contribute to the domestic country's productivity through knowledge spillovers because foreign affiliates want to invest abroad to take advantage of their own technological base instead of diffusing it internationally. Contrary to the inward FDI, they find a positive and significant effect of trade and outward FDI-related R&D spillovers on TFP. In conclusion, they argue that MNEs in relatively small countries should invest in technologically leader countries to benefit from their technological base and increase the productivity of their home country.

Javorcik (2004) criticizes many firm-level studies in the literature that search for the answer to how domestic firms' productivity in developing countries is affected by the existence of MNEs through knowledge spillovers. He thinks that this study fails to find an important spillovers effect from FDI for domestic firms because they only focused on the horizontal spillovers or intra-industry spillovers from FDI, which are the spillovers from MNEs to local firms that operate in the same industry/sector (Lenaerts & Merlevede, 2011). According to him, when domestic firms and MNEs compete in the same industry, the latter are incentivized to limit the knowledge spillovers into domestic firms through formal protection of their intellectual property, the maintenance of trade secrecy, and the payment of higher wages to reduce employee turnover. (Javorcik, 2004). Therefore, attention should be paid to vertical spillovers or inter-industry spillovers, which are the spillovers from MNEs to firms active in industries that are linked with the industry of the multinational through the supply chain (Lenaerts & Merlevede, 2011). Javorcik especially focuses on the spillovers from the connections between MNEs and their domestic input suppliers, which are backward linkages, rather than the interactions between domestic firms and their multinational input suppliers, which are forward linkages. This is because he believes that multinational firms have no reason to hinder technology from spreading to upstream industries; moreover, improved performance of intermediate input suppliers may be advantageous for them. To test his claims, he carries out a firm-level study specific to Lithuania's manufacturing firms in twenty different sectors for the period 1996-2000. He constructs proxies to measure the spillovers from horizontal, backward, and forward linkages and adds them to regression with the other factors of production. The estimation result shows a positive spillovers effect from FDI that occurs through backward linkages, whereas there is no significant spillovers effect from horizontal and forward linkages. Therefore, domestic firms benefit from the FDI in their country through supplying inputs to their multinational customers.

A specific firm-level study related to investigating the FDI's knowledge spillovers channel feature is conducted by Branstetter (2000b and 2006). He uses Japanese MNEs' FDI in the United States to examine the productivity effect of knowledge spillovers. They look at this effect from both sides: the effect of FDI-related knowledge spillovers on Japanese manufacturing firms' productivity (outward FDI) and the effect of FDI-related knowledge spillovers on American firms' productivity (inward FDI). To measure the knowledge spillovers between investing firms and indigenous firms, the number of citations made to the cumulated stock of U.S. patents of Japanese firms and U.S. citations to Japanese patents are used as an indicator of knowledge or innovative activity. The results show that knowledge spillovers in both directions, from Japanese firms to American firms and from American firms to Japanese firms, through the FDI channel.

Bitzer and Kerekes (2008)'s paper is inspired by the PL 2001 paper. They search for the answer of whether technology spillovers with FDI for ten manufacturing sectors in 17 OECD countries between 1973-2000. In addition to the industry level investigation, they develop the PL's work in two ways. Firstly, they use FDI stocks rather than FDI flows while computing the FDI-related knowledge spillovers. Secondly, they broaden the scope of PL by considering third-country effects rather than only considering the bilateral FDI knowledge spillovers between countries. This entails examining the transfer of knowledge from country C to country B and subsequently through country B’s FDI to country A. On the contrary to PL, they find that knowledge spillovers internationally through inward FDI channel and it has a significant and positive effect on productivity; however, there is no clear positive spillovers effect of outward FDI on productivity.

Liu (2008) also investigates whether FDI can affect a domestic country’s productivity through technology spillovers. He evaluates this issue from two aspects: he looks at the effects of FDI-related knowledge spillovers on both domestic firms ‘productivity levels and their productivity growth rates. Liu (2008) distinguishes the short-term level effect and long-term rate effect of FDI because domestic firms spend sources, time, and effort from current production capacity to learn from foreign investor firms in the short term; eventually, this spillovers has a negative impact on the firms’ short-term productivity level. On the other hand, in the long-term, knowledge spillovers from FDI positively impact domestic firms' productivity growth rate. The consideration is based on Chinese manufacturing firms, and the econometric model includes simply 1) a firm's equity held by foreign investors to see if foreign equity participation boosts productivity, 2) the weighted average of foreign equity shares across firms in the same two and four digit industry to capture intra industry or horizontal spillovers 3) the weighted average of FDI of upstream (backward linkages) and downstream (forward linkages) two digit industries to investigate interindustry or vertical spillovers 4) time-trend variable and its interactions with other sector variables to look at the effect of knowledge spillovers on long-term rate of productivity growth of a firm. The results show that the FDI is a channel for knowledge spillovers, and this spillovers reduces the productivity level of domestic firms in the short term while increasing their long-term productivity growth rates. In addition, despite some support for horizontal or intra-industry knowledge spillovers, backward linkages seem to be the most significant channel through which knowledge spills over to domestic firms.

Navas (2019) emphasizes the Southeast Asian and South American countries' catch-up process with industrialized countries in the last decades. However, he especially focuses on the role of FDI in these countries contributing to this process, and he does not consider all positive externalities of FDI; he looks at how technological spillovers from FDI affects these countries' productivity or economic growth. Between 1983 and 2000, when just after these geographical regions experienced divergent growth and development patterns, he concentrates on the FDI of US MNEs in these countries, and he uses the number of citations made to US patents by patents developed by firms located in the domestic country as a measure of technological spillovers across countries. Moreover, Navas (2009) includes the different types of patents' assignees to identify the owner of patent rights. The results claim that FDI increases the number of citations that host country assigned patents make to US patents, indicating FDI is a channel for international technology spillovers. In addition, these spillovers take some time, which may take at least three years, and this length varies depending on the patents' assignee.

4.1.3 Other Channels and International Technology Diffusion

The result of innovative activity mostly comprises intangible knowledge or information, which may be shared without the need for any investment or exchange of physical goods. Therefore, it is essential to recognize the importance of knowledge spillovers channels that are not clearly evident in particular transactions. These channels are called indirect or disembodied knowledge channels, such as international patenting, the Internet, scientific publications, and international conferences.

Evaluating the exact influence of direct channels on productivity presents inherent difficulties due to their ethereal nature. In this part, the studies related to these channels will be examined.

International knowledge spillovers are split into two categories by Griliches (1979): the first one is rent spillovers, which is the knowledge is transferred or diffused through the transactions of goods or investments (indirect channels), and the second one is pure knowledge spillovers, which do not necessitate economic transactions, such as technical conferences, scientific papers or labor mobility (direct channels). Due to this rationale, Verspagen (1997) suggests creating a weighting scheme of foreign R&D capital stocks that captures the knowledge spillovers from direct and indirect channels. Then, he modifies the technology flow matrices of Scherer (1982) and Putnam and

Evenson (1994), which define the transfer of technological knowledge from one sector of the economy to another. Verspagen (1997) extends this to an international level to show how technology from one sector in a particular country spread to other sectors in a group of countries. Each sector's productivity depends on its own R&D, the stocks R&D from domestic sectors, and foreign R&D stocks. For the spillovers between domestic sectors, he uses the pure knowledge spillovers matrix together with import share weights as the weights of domestic R&D stocks; furthermore, the pure knowledge spillovers matrix and the country's import shares matrix are used as a weight for foreign R&D capital stocks. Estimation results for 22 sectors in 14 countries between 1974-1992 show that both domestic and international knowledge spillovers are significant for productivity growth.

Xu and Wang (2000)'s work can be considered as one of the pioneers for including direct international spillovers channel in the discussion. This paper focuses on the FDI channel because comparatively less research has been conducted on FDI as a diffusion channel due to the complexity of MNEs' behavior and the relatively weak data of FDI. Therefore, the studies in the literature do not agree on whether FDI is a channel for international knowledge spillovers. They consider three direct channels of knowledge spillovers: the import of capital goods and inward and outward FDI. In addition to these direct channels, they add unweighted spillovers variable to represent disembodied knowledge spillovers. Furthermore, the technology gap variable, which is measured by the ratio of a country's TFP to the US's TFP, is also included in the model. According to the results, import and outward FDI-related spillovers significantly affect TFP even after controlling for the contributions of human capital and disembodied channels effects. On the contrary, inward FDI does not show such a property; however, this could be raised from the poor quality of FDI data. Moreover, the results claim that knowledge also diffuses through disembodied channels by contributing to domestic TFP growth, especially for countries that are further from the world's technological frontier.

Lee (2005) thinks knowledge is intangible and can be diffused directly without exchanging goods or investments. Therefore, most studies searching for the channels of international knowledge spillovers mostly underestimated or overlooked the direct/disembodied channels. Moreover, due to not including a significant explanatory variable, these studies were probably mistaken by the results of their models, which only focus on the knowledge embodied channels like import or FDI. At the point of measuring direct knowledge spillovers, Lee (2005) states that “Quantifying this direct impact, however, is not easy due to its abstract character, and the initial step should be to develop a suitable metric that can be used to estimate this impact.” (Lee, 2005). Within this framework, he uses a similar technology proximity to Jaffe (1986, 1988) to capture the spillovers from disembodied channels and proposes two different measures. The first measure is the weighted sum of the foreign R&D stocks, where the weights are based on patent citations, technology proximity, and rates of phone line penetration. The second measure of the direct channels aims to show the importance of telecommunications infrastructure for knowledge spillovers, and it is the weighted sum of foreign R&D capital stocks where the weights are based only on line penetration. He uses a modified version of CH’s model with a newly constructed panel dataset of 17 countries from 1971-2000. The results indicate that direct knowledge spillovers channels have a significant and positive effect on TFP, which shows that inclusion of direct channels is crucial for investigating the relationship between TFP and international knowledge spillovers. On the other hand, the effect of import-embodied foreign R&D stocks on TFP is not robust anymore with the inclusion of direct channels, which implies that knowledge may not spillover through international trade contrary to the results of CH and other followings.

Lee (2006) presents a significant study to show the relative effectiveness of different channels of international knowledge spillovers, concentrating on the direct channels especially. He brings together four different channels: disembodied channel, intermediate goods import, inward FDI, and outward FDI. He does not consider the other possible spillovers channels, such as human capital mobility or patent licensing, because of the possibility of high correlation (multicollinearity problem) between these additional channels and the four main channels mentioned above. In the case of measuring the spillovers from direct channels, he uses two different measures, like Lee (2005). The first one is the weighted sum of foreign R&D capital stock, where the weights are based on Guellec and van Pottelsberghe de la Potterie (2001, 2004)’s measure of bilateral technological proximity, which is computed using the patent grant data between countries. The second measure of direct channels is a weight that does not only depend on technological proximity but also depends on the bilateral patent citation shares. For the intermediate goods import embodied knowledge spillovers, he uses LP’s weighting scheme of foreign R&D capital stocks; inward and outward FDI embodied foreign R&D stocks are based on the PL’s method. To find the relative effectiveness of these four channels on TFP in the manufacturing sector, he modifies the PL’s econometric model for 16 OECD countries between 1981-2000. The results claim that knowledge spillovers through direct channels positively and significantly affect TFP. Moreover, contrary to the results of PL, estimations show that inward FDI is an important knowledge spillovers channel, whereas outward FDI does not demonstrate such a property. Like outward FDI, import-embodied knowledge spillovers are also ineffective on TFP which conflicts with the CH’s and LP’s claims.

Tang and Koveos (2008) examines the international R&D spillovers by comparing the different benefiting levels between developed and developing countries through both direct and indirect channels. They use intermediate goods import and inward FDI to capture the indirect knowledge spillovers and international telephone traffic to measure the disembodied spillovers. Tang and Koveos (2008) test three hypotheses to determine the relative effectiveness of knowledge spillovers among countries. The first hypothesis is whether developed countries benefit more from the trade-embodied R&D spillovers than developing countries. The logic behind this hypothesis is that new ideas, products, and technologies are more likely to arise in major global markets, and the more developed countries play a bigger role in these markets, so they should benefit more from the innovative activities. Furthermore, they state that some country-specific factors like intellectual property rights or educated human capital are significant indicators for the direction of international investment, and this is why MNEs impede investment in developing countries. This is the main concern of the second hypothesis: whether developed countries take more advantage of the FDI-related R&D spillovers. Although knowledge spillovers through disembodied channels are seen as easily accessible, utilizing the advantages of public information necessitates a higher absorptive capacity, like identifying and assimilating the information. Therefore, the third hypothesis is whether developed countries are more likely to benefit from disembodied R&D spillovers. To answer these questions, Tang and Koveos (2008) construct an economic model for 22 OECD countries (developed) and 21 non-OECD countries (developing) and look at how the R&D activities in G7 countries (leading countries) affect differently developed and developing countries' productivity depending on country-specific heterogeneity factors. The economic model contains domestic R&D stocks, foreign R&D stocks for each channel, human capital, and the level of openness variables for trade, FDI, and telecommunication as heterogeneity factors. Moreover, to assess the different benefit levels from spillovers, dummy variables for OECD countries for each channel are also included. According to the findings, knowledge diffusion from G7 countries to developed countries via trade and international phone traffic outpaces knowledge diffusion to developing nations; however, knowledge spillovers to developed and developing nations via the FDI channel do not significantly differ.

4.2 Studies Related to International Technology Diffusion in Turkey

Since one of the main purposes of this thesis is to focus on the international knowledge spillovers in developing countries by comparing them with each other, in this part, some studies focusing on Turkey as a developing country will be presented.

Lenger and Taymaz (2006) states that FDI has been seen as a crucial channel of technology spillovers for developing countries. Like other developing countries, policymakers in Turkey have also relied on the positive externalities from FDI-induced technology spillovers and implemented several initiatives to attract foreign investment since 1980. In this paper, Lenger and Taymaz analyze the determinants of domestic and foreign firms' decisions to innovate or transfer technology in Turkish manufacturing industries. Moreover, according to the data, thanks to the use of superior technologies and more innovative activities, foreign firms in Turkey are more productive than domestic firms; therefore, there might be some technology spillovers from these firms to domestic firms. Then, they also investigate this possibility through three channels: horizontal linkages, vertical linkages, and labor turnovers. Furthermore, Lenger and Taymaz distinguish the spillovers in low- and medium-high technology industries separately. The results of the study indicate that labor turnover is the principal source of technology spillovers. On the contrary, horizontal spillovers does not affect domestic firms' productivity, and the effect of vertical spillovers is not clear.

Gorkey (2014) criticizes the studies in the literature for mostly focusing on the knowledge spillovers for developed countries, and she states that the growth of the global economy has changed noticeably due to the growth rates of emerging countries. In this regard, it is crucial for emerging economies to accelerate technological development to increase productivity and growth. For this reason, international technology spillovers have great importance for emerging countries, which cannot produce enough domestic technology or knowledge, and more attention should be paid to the spillovers in these countries. Then, she investigates the relative effectiveness of international technology diffusion channels on the manufacturing industry's productivity in emerging countries in the EU and Turkey. In the investigation, she considers foreign R&D intensity, which is the weighted sum of R&D intensities of G7 countries where the weights are the emerging countries' bilateral import shares with G7 countries, the import of technology goods, and inward FDI as the channels of spillovers. In addition, the human capital factor is also included in the model for its direct effect on TFP and its indirect effect as a proxy for absorptive capacity for international spillovers. According to the results, Gorkey (2014) claims that foreign R&D intensity, import, and human capital positively affect the TFP of the manufacturing industry; however, FDI and the interaction variables of channels with human capital do not affect TFP.

Fatima (2016, 2017) conducts a firm-level study for the Turkish manufacturing industry to examine how inward FDI in Turkey affects the productivity of domestic firms as a channel of international knowledge spillovers. The study takes the investigation one step further and looks at how the absorptive capacity of Turkish firms affects the gains from FDI-related spillovers, whether there is a differential effect of absorptive capacity on different types of FDI-induced spillovers, and whether this differential effect changes with the quantile levels of firms. She uses the inverse of the technology gap between domestic and foreign-owned firms as the proxy for the absorptive capacity, and she uses intra-industry (horizontal linkages) and inter-industry (backward and forward linkages) spillovers for different types of FDI-induced spillovers. For the Turkish manufacturing firms operating in five different quantiles of the productivity distribution between 2003-2010, the results show that, while holding the absorptive capacity of firms constant, a statistically significant difference exists in the effect of horizontal and forward linkages across different quantiles. For horizontal or intra-industry spillovers, local firms' productivity is adversely affected by the existence of foreign firms in the same industry; moreover, the firms in a higher quantile are less vulnerable to the negative effects of horizontal spillovers. For inter-industry spillovers, this type of FDI-induced spillovers increases the productivity of domestic firms, and the benefit of the firms with higher quantile levels is more obvious. In addition, for a given level of FDI, an increase in absorptive capacity makes smaller the technology gap, creates gains from horizontal linkages for all quantile levels, and creates a positive effect for firms located in lower quantiles through forward linkages.

4.3 The Relation Between International Technology Diffusion and Absorptive Capacity and Institutional Settings of Countries

Countries are likely to get different benefits from foreign technology spillovers depending on their trade pattern, degree of openness, human capital, the set of domestic conditions and, geographic localization, etc. For instance, countries with a greater degree of openness are likely to benefit more, particularly through the import channel, or countries with larger human capital and a much simpler and more friendly institutional framework for business activities may benefit more from the FDI channel.

The presentation of these facts in a stylized manner raises some assumptions regarding some of the possible factors for why some developing countries may have benefited more than others from technology spillovers. In this part, the studies searching for the reasons behind heterogeneity across countries will be presented.

Engelbrecht (1997) states that R&D can be seen as a particular type of human capital because it is created and also used by human capital; therefore, human capital is another important source of innovative activity or knowledge besides R&D. It performs a unique function in economic growth processes through its direct and indirect impacts on TFP. He believes that to see the true relationship between international R&D spillovers and TFP, all sources of productivity must be considered. For this reason, Engelbrecht (1997) reconsiders the CH's results by including human capital in the model. He also uses a productivity catch-up factor, a ratio of a country's real per capita GDP to real US per capita GDP, and adds its interaction with human capital into the model to capture the international knowledge spillovers. According to the results, foreign and domestic R&D protect their effect on TFP even after taking human capital into consideration. Furthermore, human capital directly impacts TFP as a factor of production and as a means of international knowledge spillovers related to productivity catch-up among countries. Estimates appear to corroborate the dual function of human capital in the economic growth process.

Del Barrio-Castro, Lopez-Bazo, and Serrano-Domingo (2002) also sees human capital as an essential factor for TFP growth and a significant determinant of a country's absorptive ability from international R&D spillovers. To take this country-specific factor into international R&D spillovers analysis, he uses Engelbrecht (1997)'s economic model; however, he uses different human capital data with other small differences. The estimation results indicate that human capital has a stronger impact on TFP than domestic and foreign R&D stocks. Moreover, the effects of domestic and foreign R&D stocks decrease dramatically with the inclusion of human capital.

Human capital is a crucial factor for international knowledge spillovers because it is the one that understands foreign high technologies and absorbs them for domestic use. At this point, Kwark and Shyn (2006) criticize the previous studies investigating the relationship between TFP and knowledge spillovers, for not considering human capital or for only considering the direct effect of human capital on TFP. They state that human capital also indirectly affects TFP through its absorptive impact on international knowledge spillovers. Then, they re-examine the import-embodied international spillovers by including human capital and trade openness factors (direct effect on TFP) and their interactions with foreign R&D stocks (indirect effect on TFP). In this investigation, however, for trade openness, the ratio of the recipient country's imports from industrial countries to its GDP is used rather than the ratio of a recipient country's total import to its GDP to reflect the high technology or R&D embodied in imported intermediate goods. Furthermore, they propose a new measure for the weighting scheme of import-embodied foreign R&D stocks: the ratio of the recipient country's bilateral import from an industrial country to the industrial country's total export. The investigation is based on 21 industrial countries and 82 less developed countries, and the knowledge spillovers from industrial countries. In Kwark and Shyn (2006)'s economic model, TFP depends on domestic and foreign R&D stocks, human capital, and the interactions of foreign R&D with human capital and trade openness. The estimation results show that the significant and positive direct effect of foreign R&D on TFP becomes insignificant when the interaction variable with human capital (indirect effect) is included in the model. This proves that it is important to trade with advanced countries to take their knowledge or technology embodied in goods; however, it is more important to have a well-educated human capital to be able to absorb and implement this knowledge. On the contrary to human capital, the direct effect of trade openness on TFP or its indirect effect on TFP through the interaction with foreign R&D stocks is insignificant.

Institutions are regarded as increasingly important country-specific determinants of productivity and, consequently, economic growth. They are crucial in specifying countries' absorptive capacity from international knowledge spillovers and the level of domestic R&D creation. For this reason, Coe, Helpman, and Hoffmaister (2009) conducts a study to prove that the different institution structures between countries affect their productivity growth. The ease of doing business[14], the quality of tertiary education, the strength of intellectual property, which is measured by the patent protection index, and the origins of the legal system[15] are the possible institutional effects in this paper. Coe et al. (2009) put these variables into a modified regression of CH to see how their interactions with domestic and foreign R&D stocks and human capital, approximated by average years of schooling, affect TFP. For the ease of doing business and quality of tertiary education systems, there are dummies that show whether the country is in the top, middle, or bottom third of the 24 countries. For the

[14] An average ranking of countries based on the ease of performing the subsequent ten activities—establishing a business, managing licenses, hiring employees, registering property, obtaining credit, safeguarding investors, remitting taxes, transnational trade, enforcing contracts, and dismantling operations—is referred to as the "ease of doing business." (*Doing Business 2008*, 2007)

[15] The origins of legal systems in either Scandinavian, English, French, or German law (La Porta et al., 2008).

legal origins, there are also dummies indicating the country's legal origin is French, Scandinavian, or German. Finally, the patent protection index enters the regression as an additional determinant of TFP, and its interactions with domestic and foreign R&D capital stocks also enter the regression. The results claim that the countries have a relatively higher ranking in ease of doing business, and the quality of tertiary education systems take more advantage from domestic and foreign R&D stocks and human capital. Moreover, strong patent protection means higher TFP levels. Finally, the countries with legal systems originating in France or Scandinavia benefit less from their own and foreign R&D capital.

Seck (2009) conducts a very similar work to Coe et al. (2009) to investigate what extent developing countries benefit from the R&D activity in advanced countries and which country-specific factors affect the heterogeneity in their absorptive for spillover gains. However, he only focuses on developing countries because he thinks knowledge spillovers are crucial for countries that cannot exhibit enough R&D activity. In addition to trade openness and human capital, ease of doing business, patent protection, and historical origin of legal systems are considered institutional factors to assess how countries' ability to benefit from international knowledge spillovers differ. He considers import and inward FDI as a channel of R&D spillovers, and he adds all country-specific factors' interaction with import and FDI-embodied foreign R&D stocks separately into the model. Using institutional variables is very similar to Coe et al. (2009). For ease of doing business, he uses a dummy variable for the countries ranking in the top half of the list; similarly, for the origin of legal systems, he also uses a dummy variable for countries with a legal system based on British rather than French. Seck (2009) constructs this model for 47 developing countries and G7 countries, which are responsible for a large part of world R&D. The results show that countries with a higher pool of human capital, more open to international trade, and stronger institutions benefit more from foreign technology. This confirms that there is an important heterogeneity in the knowledge spillovers gains across developing countries.

Fracasso and Vittucci Marzetti (2013) test the relationship between a country's level of TFP and import embodied foreign R&D capital stocks from a different perspective.

In addition to the trade, they consider the geographical distance as a source of the international R&D spillovers and analyze whether R&D spillovers are global or local; in the case of a negative answer, to what extent the impact of international R&D spillovers on domestic TFP depends on import. They first test, via a randomization method used by Keller (1998), whether R&D spillovers are global, which means that all countries could absorb knowledge from a common and global pool, or R&D spillovers are localized, meaning spillovers decay with geographical distance. They reject the hypothesis of a “global pool of technology” and show that there are partitions of countries associated with relatively strong/weak knowledge spillovers. After reaching this conclusion, they examine whether geographical distance is the only source of knowledge spillovers or if there is still room for an additional effect of trade in these spillovers. To consider both distance and trade in the international diffusion of knowledge, they add “trade openness” to Keller’s (2002) model by using the enlarged sample of countries employed by Coe et al. (2009). They find that trade openness considerably increases the elasticity of TFP, so international trade remains positively related to R&D spillovers even once geographical proximity is already accounted for in the specification. This result conflicts with the result of Keller (2002), who claims that international trade plays no role once geographical distance is accounted for.

Krammer (2014) states that with globalization, technological innovation, and its diffusion boosted in recent decades, R&D efforts have become the primary driver of productivity or economic growth; nevertheless, a few countries possess operational frameworks and financial means necessary to exploit these technological innovations effectively. Therefore, the other countries, less developed ones, mostly depend on foreign technology to reduce the gap between developed countries. In this regard, especially for developing countries, it is very crucial to figure out the technology spillovers channels and to identify their relative effectiveness. To manage these issues, Krammer (2014) considers two embodied spillovers channels, imports of intermediate goods and inward FDI, and two disembodied channels, foreign patenting in the recipient country and direct licensing of foreign technologies. His main aim is to compare the effectiveness of these channels for developed and developing countries by including country-specific absorptive capacity factors. Then, he uses 47 developed

Western countries and transition countries from Eastern Europe and Central Asia from 1990-2009 and considers 25 OECD countries as the source of international knowledge spillovers. He uses human capital and domestic R&D stocks for the absorptive capacity of countries. The estimation results claim that all channels in the model transfer technology internationally, and trade is the most effective channel for productivity gains from international spillovers. Moreover, while foreign patenting is more effective in developed countries, trade, FDI, and foreign technology licensing are more effective channels for transition countries. In addition, the overall benefits from international technology spillovers are greater for transition countries, which confirms the importance of foreign technology in developing and catching up with developed countries.

Naveed and Ahmad (2016) states that regions separated by international borders are distinguished by differences in policies, culture, language, regulations, or institutions, whereas regions within the same country are more connected. For this reason, they argue that technology spillovers may have different impacts on productivity depending on the type of border between regions. In this regard, they criticize the studies in international knowledge spillovers literature for not distinguishing the internal regional spillovers from the spillovers from neighbouring regions within the same country and from neighbouring regions across the international borders. Furthermore, they think that ignoring the different borders effect may lead to under or overestimate the effect of technology spillovers on productivity. Therefore, Naveed and Ahmad (2016) construct an econometric model that separately shows the impacts of internal neighbour spillovers and international border spillovers on productivity. For the analysis, they use 204 regions, 86 of which have a border with a neighbouring region in another country, for 16 EU countries between 1999 and 2010. The results of the study show that while technology spillovers from neighbouring regions across the international borders are statistically insignificant, the spillovers mainly come from the internal neighbouring regions. This situation indicates that technology spillovers are geographically localized.

Whether trade openness is advantageous for a country's economic growth or not is an increasing debate with globalization. Gonçalves, Taveira, Labrador and Pio (2021) take this question at the centre of their work and investigate whether trade openness can operate as a knowledge spillovers channel both developed and developing countries in both long-term and short-term. With 58 countries for a period of 1970-2014, they use domestic knowledge stocks of countries, foreign knowledge stocks, which is weighted with bilateral import shares (LP method), human capital index, openness variable measured by import plus export to GDP, to capture the effect of permanent openness level and trade openness in first difference to capture the effect of short-run openness to TFP growth rate. Because of some endogeneity issues, they use the generalized method of moments (GMM) estimation procedure. Consequently, Gonçalves et al. (2021) find that trade openness is a channel for knowledge spillovers for all countries, and it affects TFP growth positively. However, for low-income and emerging countries, trade openness is effective only in the short-run and it affects these countries' productivity growth negatively. These results cast doubt on the benefits of trade openness for poor countries, which could serve as evidence supporting Rodrígguez & Rodrik's (2000) argument that the presence of certain trade barriers may be favorable for the domestic development of knowledge and technology. For high- and middle-income countries, there are permanent effects of trade openness on productivity growth and a non-significant short- run link between these variables.

A very recent study is conducted by Haq, Hussain and Amin (2022) to investigate the effect of countries' absorption capacity on international technology spillovers. They consider two different proxies for absorptive capacity: human capital and domestic R&D stocks. In order to measure the spillovers from foreign R&D stocks, they take into account the import and inward FDI as channels. The investigation is for five Asian countries between 1972 and 2018, and there are two different econometric models. One is for assessing the effect of knowledge spillovers on economic growth and to investigate the role of absorptive capacity, and the other one is for seeing the effect of knowledge spillovers on TFP growth while observing the role of absorptive capacity. The results indicate that international knowledge spillovers have significant and positive effect on both economic and TFP growth for all channels. Furthermore, countries with higher level of domestic R&D stocks benefit more from technology spillovers in the process of economic and productivity growth whereas human capital does not have important role in the absorption of foreign technology.

CHAPTER V

REVIEW OF LITERATURE ON TOTAL FACTOR PRODUCTIVITY CONVERGENCE

5.1 Brief Literature Review on Convergence Theory

Less developed countries are primarily concerned with advancing their level of development. This multifaceted and ambiguous goal can be summed up in the convergence of these nations with those regarded as developed. At the regional level, achieving this convergence has also emerged as one of the primary goals. The study of economic theory becomes relevant in the quest for the means to accomplish this goal: What does the theory posit regarding the convergence process? How is that clarified? Can any economic strategy facilitate the attainment of this convergence? (Escot, 2001).

The convergence phenomenon in empirical growth dynamics has received significant study, beginning with neoclassical growth models and extending to endogenous growth theories. The neoclassical growth model provides support for the idea of convergence, but the endogenous growth model takes into account the lack of convergence (Islam, 1995).

The neo-classical models suggest that real income per capita convergence can occur in two ways: absolute convergence and conditional convergence. Absolute convergence examines whether, in a given country, real per capita income converges to a steady-state value independent of other conditions. Conditional convergence entails the convergence of each country towards a distinct level of real income per capita. Variations in the long-term levels of real per capita income among countries result from disparities in factors such as the pace at which savings accumulate over time, the rate at which the population grows, and other relevant factors (Miller & Upadhyay, 2002).

Furthermore, according to the neoclassical growth model, there are two distinct forms of convergence that are discussed in the literature, namely σ (sigma) convergence and β (beta) convergence. β-convergence is a phenomenon observed in a collection of economies where the rate of per capita development is typically inversely proportional to the initial level of output or income per individual (Barro & Sala-i-Martin, 1992). That is, nations characterized by a low real GDP per capita experience more rapid rates of economic growth in comparison to nations with a high real GDP per capita. The convergence of the σ-type examines whether real GDP per capita distribution decreases over time. In other words, σ-convergence suggests that with time, the real GDP per capita distribution across nations becomes more tightly distributed, hence decreasing some degree of dispersion (Miller & Upadhyay, 2002).

However, both methods generally have some constraints, especially regarding estimation, and are heavily criticized in literature. For example, opponents of β-convergence contend that if every country finally attains the same level of wealth as all other countries, then the distribution of the examined variable should vanish over time (Quah, 1996). Similarly, the lack of σ-convergence does not imply that countries do not converge; rather, the null hypothesis of σ-convergence may be rejected if transitional dynamics are present in the data (Bliss, 2000).

In addition to the conventional concept of β and σ- convergence, there is an alternative method of convergence, stochastic convergence. The concept of stochastic convergence, which emerged in the early 1990s and was extensively discussed by Bernard and Durlauf (1995), relies on a time series method rather than the cross-sectional technique used in β convergence. In contrast to the β-convergence paradigm, which focuses on the current state and the lagged influence of GDP on current growth, stochastic convergence considers the expected future differences in GDP levels between different countries. The fundamental idea in the context of stochastic convergence is to anticipate that the disparity in GDP per capita will converge to zero over an indefinite period (Witkowski & Próchniak, 2015).

Stochastic conditional convergence can be assessed by utilizing the Lagrange multiplier (LM) and residual augmented least squares Lagrange multiplier (RALS-LM) unit root tests, as proposed by Lee and Enders (2012) and Meng et al. (2014). These unit root tests provide strong evidence supporting the "catch-up" idea, including the presence of endogenous breaks (Rath & Akram, 2019).

5.2 Studies Related to Total Factor Productivity Convergence

Productivity is a quantitative assessment of the efficiency of an economy's resources to produce goods and services. Krugman states, “Productivity isn’t everything, but, in the long run, it is almost everything” (Krugman, 1994, p.11).

Productivity is the primary factor determining a country’s living standards for extended periods (Johnson et al., 2005). That is, variations in productivity levels account for a substantial amount of the variances in per capita income among countries. Moreover, it is established that technology is crucial in determining productivity levels (Hall & Jones, 1999). Therefore, analyzing productivity performance between countries is crucial for understanding long-term economic growth. It seeks to determine whether less productive nations are narrowing the gap with the most productive countries and, if so, the speed and methods of this convergence (Bernard & Jones, 1996a).

Productivity convergence in literature refers to the idea of "catch up," wherein countries with lower productivity experience faster growth to bridge the gap with countries possessing higher productivity. Examining TFP growth convergence is critical for two reasons. To begin with, an increase in TFP is one of the ways by which a country's standard of living can be raised by increasing real purchasing power (Krugman, 1994). Second, according to Baumol et al. (1994), by forming a club convergence, a relatively limited collection of countries can undergo a process that puts their productivity and living standards closer.

Furthermore, analyses of income convergence among nations provide insights into how a low-income country can narrow the gap regarding per capita income with a high-income country. However, it does not necessarily reveal whether this convergence is driven by an increase in productivity or the accumulation of multiple input factors. Hence, the analysis of productivity convergence suggests the potential for the transmission of technology from advanced nations to less developed nations, which is crucial for maintaining a continuous growth trajectory (Rath, 2019).

Due to the significant impact of the productivity gap on the progress of developing countries in catching up to rich countries, the literature has extensively examined the convergence of total factor productivity (TFP). This section will give a selection of works on this topic.

Significant literary works effectively demonstrate the significance of analyzing productivity convergence among countries by utilizing various data sets and diverse methodologies for measurement. One of these works is conducted by Barro and Sala-i-Martin (1991). They aim to analyze the expansion and distribution of individual income in the US states and regions since 1880 and establish a connection between the trends observed in particular states and the overall behavior of regions. They take the non-agricultural portion of the gross state product and break it down into the value added per worker for eight industries. The most important result is that there is a large amount of convergence occurring among these different industries of production, particularly in manufacturing, and less developed states experience more rapid growth, both in terms of the overall gross state product per capita and in terms of labor productivity across different sectors of production. Similarly, Barro and Sala-i-Martin (1992) examines convergence in per capita income and productivity across the 48 states of the USA using a neoclassical growth model and concludes that the U.S. states exhibit a clear demonstration of convergence.

Bernard and Jones (1996a) aim to show whether aggregate productivity trends reflect industry trends in the case of convergence. Firstly, they test for the country-level convergence for 14 OECD countries between 1970 and 1987 by using neoclassical approaches, namely sigma and beta convergence, and they look at both income and productivity convergence, where productivity is measured by labor productivity and TFP separately. The results of aggregate-level analyses support the income and productivity catch-up among these countries. Secondly, the authors examine the evidence derived from the sector-specific data to comprehend the underlying factors behind this compelling indication of convergence in overall industry productivity. Hence, Bernard and Jones create six widely categorized sectors for each economy and test whether labour productivity and TFP within each sector converge across countries. The findings for individual industries exhibit divergent behavior patterns contrary to the aggregate productivity. While the manufacturing industry has negligible or no convergence in productivity, other industries, particularly services, have compelling evidence supporting convergence.

Bernard and Jones (1996b) state that the scholarly research on convergence has primarily concentrated on aggregate output and productivity, both in theory and practice. For this reason, they aim to examine if the emphasis on aggregate results conceals significant fluctuations in productivity movements at the sectoral level by refraining from engaging in the neoclassical or endogenous growth theories argument. They analyze data from six broadly categorized sectors and evaluate the evidence supporting or refuting the convergence of TFP within sectors across different countries. The results for 14 OECD countries between 1970 and 1987 claim a significant variation in TFP among different sectors, and certain industries exhibit convergence across countries within sectors, whereas others do not. Furthermore, the economy's non-manufacturing sectors, particularly the services sector, are the main drivers of TFP convergence across OECD countries; however, there is not enough evidence for TFP convergence in the manufacturing sector.

The studies related to income convergence hypothesis in literature consistently indicate that there is evidence of absolute convergence solely among developed countries; however, studies encompassing developed and developing countries typically do not discover conclusive evidence of absolute convergence. Evidence of conditional convergence arises in samples including these two country groups. Moreover, besides income convergence, few studies related to TFP convergence exist. In this regard, Miller and Upadhyay (2002) conduct a study to test absolute and conditional convergence in both income per capita and TFP for a sample of 83 countries between 1960 and 1989 by dividing this sample into subsets of countries categorized by their income levels specifically low, middle, and high. Firstly, the authors calculate TFP using a simplified aggregate production function model. Then, they test for the convergence of income and TFP by looking for both β and σ-convergence. The results uncover more compelling evidence of TFP convergence than real income convergence. Moreover, the results also claim that there is relatively less evidence of TFP convergence for high-income countries and significant evidence of it for low- and middle-income ones, which collaborates with the idea that technological progress is primarily a public good rather than a private one.

Liberto and Usa (2010) argue that when studying convergence between regions, it is important to consider the potential for spatial spillovers across different regions, which might result in spatial dependence. For this reason, they intend to investigate the presence of technology convergence among 199 European regions from 1985 to 2006. Firstly, they analyze the presence of TFP heterogeneity and dynamics by using a typical neoclassical convergence equation framework in which TFP levels are assessed using growth regressions that account for the factor accumulation, specifically physical capital, to income convergence separately. They also indicate that it is not easy to estimate TFP levels and identify the impact of technology diffusion within the income convergence framework. The author's first analysis results confirm TFP heterogeneity across European regions; this disparity is closely linked to variations in income per capita. Secondly, Liberto and Usai examine the impact of space on the development of regional TFP distributions using conventional and cutting-edge explanatory spatial data analysis methods. Furthermore, they divide their time into two sub-periods according to the introduction of IT technologies, which may be a significant source of a TFP and its convergence. Then, by emphasizing the potential for TFP distribution and its dynamics over time to be associated with geographical localization and spatially dependent phenomenon, the results of different methods show that there is not enough proof of a worldwide phenomenon of TFP convergence, as the variation in the estimated TFP levels has remained consistent throughout the time. Moreover, there is a distinct polarization of wealthier areas in the northern regions of Europe, while southern regions experience a decline in productivity. Overall, a small group of TFP leaders in Europe is forming and moving away from others while the group of low TFP areas is growing.

Rath and Akram (2019) re-evaluate the convergence of TFP by using the latest econometric techniques. They criticize the neoclassical convergence models for assuming a single steady-state equilibrium path for all countries. Therefore, they use stochastic conditional convergence rather than standard neoclassical beta and sigma convergence by employing the newest LM and RALS-LM unit root tests. Thanks to this convergence notion, instead of following the single steady-state equilibrium, they evaluate whether a group of countries that form different clusters follow the same transition path to reach the steady-state. Rath and Akram use 29 OECD and 44 developing countries from 1970 to 2014, and they divide developing countries into subgroups like Africa, Latin America, Asia, and the Caribbean. Firstly, they test whether these developing countries' TFP converge to the average TFP of OECD countries as a frontier, and the results confirm that each developing country demonstrates a propensity to converge in TFP with the average of OECD countries. Secondly, the authors examine the region-based convergence case, and the findings claim that all regions are also converging; however, the convergence speed varies by region.

Although there have been numerous studies on the convergence of income levels across both developed and developing countries, there is a lack of research on convergence productivity that specifically focuses on trade blocks. In this regard, Rath (2019) examines the phenomenon of production convergence among the five original Association of Southeast Asian Nations (ASEAN) countries, which are Indonesia, Philippines, Thailand, Malaysia, and Singapore, during the period from 1968 to 2014. According to Rath, because these five countries have formed a trade bloc, it is worthwhile to investigate their productivity convergence. For the investigation, he criticizes the neoclassical approach of convergence, namely beta and sigma convergence, and he uses the LM and RALS-LM unit root tests to see whether these five countries' productivity is converging individually. Moreover, Rath also uses Phillips and Sul (2007) panel club convergence method to detect whether these countries' productivity converges as a group. The results confirm the individual and group productivity convergence for these countries.

5.2.1 Studies Related to Total Factor Productivity Convergence and International Technology Diffusion

As previously stated, technology is crucial in elucidating income disparities among countries. Physical and human capital accumulation is also important but does not account for a significant portion of the current cross-country income disparities (Easterly & Levine, 2001; Prescott, 1998). Differences in the rate of technological change among countries directly impact the global distribution of income.

Given the partially public character of technology, the tests for TFP convergence offer fresh perspectives on the diffusion, acceptance, and convergence of technical advancements across countries. From this perspective, the technological gap between the leading nation that develops technology and the following nation that employs and replicates it would be diminished (Escot, 2001). In other words, if technology can cross international borders, then TFP should converge. This is why the significance of open economy versions of innovation-driven theoretical growth models has emphasized the crucial role of international technology diffusion in elucidating the process by which lagging countries catch up with technologically advanced nations (Frantzen, 2004).

Hence, international technology spillovers are crucial in determining the average income per person worldwide. This suggests that the extent of worldwide technological diffusion determines income convergence. Strong diffusion is a driving force toward convergence since it equalizes technological gaps between countries. On the other hand, the absence of international technological spillovers supports divergence (Gong and Keller, 2002).

In general, the diverse body of literature concerning technological catch-up has elucidated the critical significance of technology diffusion on economic growth and convergence processes between nations. In the following section, a few studies that have shed light on the crucial role that international technology diffusion plays in the convergence of income and total factor productivity will be presented.

Escot (2001) focuses on how international technology diffusion affects the income per capita convergence across countries through its effect on technological progress. He uses the technological catch-up hypothesis, which is the assumption on the approximation of technology levels in different countries, to suggest that a country with initially lower technical advancement will have a potential advantage over others regarding technological improvement and growth opportunities. In this regard, Escot adds the relative difference in technology levels between the leader country, in this case, the USA, and the follower country into the neoclassical exogenous Solow-Swan growth model to represent the technological catch-up or the international technology diffusion process. Moreover, like in the classical convergence equation, income per capita growth also depends on the traditional convergence indicator derived from diminishing returns to capital. The estimation results of this convergence equation suggest that both international technology diffusion and diminishing returns on capital influence income convergence. Moreover, the results support the conditional convergence idea of the neoclassical model, which is the disparity in income levels will persist in the long-run, and this conditional convergence can be attributed to two key factors: falling marginal productivity of accumulated factors and the gradual technology diffusion process.

Bloom, Canning, and Sevilla (2002) defend differences in technology level or TFP gap between countries can close with the international technology diffusion, and they criticize the views that take TFP same for all countries or enable TFP variations between countries but believe that these variations remain constant indefinitely. In this regard, they intend to test the evolution of TFP and allow for a catch-up term to see whether there is conditional convergence of TFP through technology diffusion. Then, they construct a model that shows how inputs and TFP affect output and how TFP evolves over time. In this model, the growth output is dependent on i) the growth of inputs, capital, labor, and human capital, ii) the growth of TFP and macroeconomic shocks, iii) the catch-up term, which is the multiplication of the TFP gap between countries and the rate of convergence to steady state which measures the speed of technology diffusion iv) the interaction terms of geographic variable and institutional quality variable with long-run TFP growth rate. The estimation results between 1960 and 1990 give conditional convergence, which is strong evidence for international technology diffusion. Moreover, every country converges its own steady-state TFP level because of the differences in geographic and institutional factors, and income differences across countries are mostly explained by the TFP gap in the model.

There is a substantial body of empirical work that has been conducted on the topic of convergence of income per capita or productivity among countries; however, the majority of these works utilize regression analyses and are grounded in the transitional dynamics of the basic neoclassical model of economic growth in which these dynamics is commonly recognized for its conditional convergence, arises from the property of diminishing returns to capital. Frantzen (2004) indicates that, with the emergence of new innovation-driven growth models, technology is not an exogenous variable anymore, and technology can diffuse from developed countries to developing ones with a more globalized world. In this regard, he asses that the convergence mechanism should be modified and should include the international technology spillovers effect because the less developed countries may prefer to imitate foreign technology rather than innovate, and this process can help them to catch up with the countries at the technological frontier. However, he also adds that there is little empirical research that allows for TFP convergence through international technology spillovers, and these studies are country-level studies, which makes it impossible to detect the internationally tradable sectors that cause convergence through spillovers. For these reasons, Frantzen (2004) proposes a TFP growth equation that includes the initial level of technology gap between the technological frontier and non-frontier country. This variable represents the catch-up mechanism through technology diffusion. In addition to the catch-up variable, TFP growth also depends on domestic R&D intensity and human capital stock and the autonomous country-specific growth rate of TFP in the model. The results for 22 manufacturing sectors in 14 OECD countries between 1970 and 1995 confirm the importance of international technology diffusion for the conditional convergence between countries and TFP growth.

Minh, Nguyen, and Thi Thu Ha (2014) states that the process of productivity convergence can be facilitated by technology spillovers, which allow low-technology firms to bridge the gap with high-technology ones, and this is particularly beneficial for new market entrants who may not have the resources to invest in R&D or acquire new technologies. To see how low-tech firms catch-up with the high-tech ones, they propose some models for the Vietnamese firms. Firstly, they construct an econometric model to measure the TFP. The second model is the unconditional convergence process in which the growth rate of TFP is simply a function of the initial productivity. The third model is constructed for the conditional convergence of TFP under the impacts of technological spillovers. In this model, for domestic and international technology diffusion, they construct technology transmission channels and integrate them into the model. These channels separately catch the effect of horizontal, backward, and forward spillovers between high-tech and low-tech firms. The estimation results for the firms in manufacturing and service industries between 2000-2012 indicate that technology diffusion substantially accelerates the rate at which firms converge. Moreover, the rate at which the conditional convergence model incorporates technology spillovers is faster than the unconditional convergence model, which does not consider technology spillovers.

Maryam and Jehan (2018) states that as an indicator of technological progress, TFP and TFP convergence have been important phenomena in the last decades, especially for developing countries. Due to the TFP gap between countries, some measures must be implemented to maintain sustainable economic growth and productivity for less developed countries. According to Maryam and Jehan, one of these measures is international technology diffusion. They think that to be able to analyze the impact of technology diffusion on TFP and its convergence process, two different indicators, namely trade openness and FDI, can be used as a measure of or channel of technology diffusion. For the investigation, they construct an economic model where TFP growth is the dependent variable. The first independent variable is the TFP gap, which is the difference between the TFP of each non-frontier country and the TFP of the frontier country; in this case, the frontier country is the USA. The second and third variables are trade openness and FDI, which show these variables' direct effect on productivity. In addition to their direct effect, their interaction terms with the TFP gap are included in the model to examine the effect of technology diffusion on the process of TFP convergence. The authors also add human capital and real exchange rate as regressors. The result for 91 developing countries between 1960 and 2015 claims that the countries farther from the frontier country will experience faster TFP growth and a catch-up process. Furthermore, in addition to the positive effect of trade openness and FDI on productivity growth, their interaction terms with the TFP gap are negative and statistically significant, which shows that an increase in these two variables triggers the convergence of TFP as a channel for international knowledge diffusion.

Tica and Šikić (2019) investigates the possible TFP convergence between EU countries. Using neoclassical growth theory and literature on international technology diffusion, they examine the changes in the relative TFP among EU members and determine the relative significance of various channels of technology diffusion to see how these channels help reduce the technology gap with the frontier countries in the EU. Moreover, Tica and Šikić include absorptive capacity factors like human capital or trade openness to assess how these country-specific factors play a role in international technology diffusion. For the investigation, firstly, the authors conduct Phillips and Sul (2007) log t-convergence test to detect TFP convergence clubs among the countries in the EU. This test's first result rejects the hypothesis suggesting the entire convergence for EU members of 28 countries. When they continue to find TFP convergence, they reach two subsets of convergence clubs; the first one involves 16 more newly member countries, the peripheral EU countries, and the second one involves mostly old EU member countries. After this TFP convergence test, Tica and Šikić employ panel vector autoregressive (VAR) model analyses to examine the mechanism by which technology is diffused among EU members as well as within and between convergence clubs. The findings show that FDI and R&D are the key determinants in driving technological progress across the EU sample. Surprisingly, the results challenge common beliefs by showing that human capital and trade openness are the primary means of TFP spreading to peripheral EU countries. The overall findings indicate that closing the productivity gap across countries is a heterogeneous process that varies from country to country.

CHAPTER VI

MODEL, DATA AND METHODOLOGY

In the previous chapters, the studies related to the process and channels of international technology diffusion, the heterogeneity problem across countries in this process, and the role of technology spillovers in TPF convergence are shown. This chapter aims to construct an econometric model to show how TFP in developing countries is affected by international technology diffusion and to show the relative effectiveness of different channels. In addition to the TFP model, the impact of international technology spillovers on TFP convergence will also be analyzed with a different model. The results of these analyses will be given in a comparative perspective.

6.1 Country Selection

In this scenario, there are 46 developing countries[16], including Turkey, and 7 developed countries, which are G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States). The timeline for the analysis is between 2000-2019.

The measure of innovative activity in these analyses is R&D stocks. As an assumption, G7 countries are the only source of innovative activity in the world; therefore, the effect of developing countries' domestic R&D on TFP is ignored because of the relatively little innovative activity in these countries.

The developing countries were selected based on the country classification of the International Monetary Fund (IMF), United Nations (UN), and World Bank (WB).

[16] Argentina, Bahrain, Brazil, Bulgaria, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, Guatemala, Honduras, Hong Kong, Hungary, India, Indonesia, Iran, Israel, Jamaica, Jordan, Kazakhstan, Kenya, Malaysia, Mexico, Morocco, Nicaragua, Panama, Paraguay, Peru, Philippines, Poland, Qatar, Romania, Russian Federation, Saudi Arabia, Serbia, Singapore, South Africa, Republic of Korea, Thailand, Trinidad and, Tobago, Tunisia, Turkey, Ukraine, Uruguay, Venezuela.

Firstly, the least developed countries (LDCs) were subtracted from the list of developing countries in the UN's World Economic Situation and Prospects (WESP) 2023 report. Then, this country list was compared with the emerging and developing country list of the IMF, and some suitable countries were added. According to the WB's income-based country classification, some countries were also elected from the list.

To reach more similar developing countries, their trade volume with G7 countries, their R&D expenditures and patent applications by non-residents were also considered. Finally, the 46 developing countries[17][18], shown in Table 6.1, were selected and grouped according to their WB income level for easy comparability.

Table 6.1 List of Developing Countries According to Their Income Levels[19]

High-Income	Upper Middle-Income	Lower Middle-Income
BAHRAIN	ARGENTINA	UKRAINE
CHILE	BULGARIA	EGYPT
HONG KONG	COLOMBIA	HONDURAS
HUNGARY	COSTA RICA	INDIA
ISRAEL	TURKEY	IRAN
PANAMA	ECUADOR	KENYA
POLAND	GUATEMALA	MOROCCO
QATAR	INDONESIA	NICARAGUA
REPUBLIC OF KOREA	JAMAICA	PHILIPPINES
ROMANIA	BRAZIL	TUNISIA
SAUDI ARABIA	KAZAKHSTAN	JORDAN
SINGAPORE	MALAYSIA	VENEZUELA
TRINIDAD AND TOBAGO	MEXICO	
URUGUAY	PARAGUAY	
	PERU	
	RUSSIAN FEDERATION	
	SERBIA	
	SOUTH AFRICA	
	THAILAND	
	DOMINICAN REPUBLIC	

[17] The data availability was also considered.
[18] China was excluded from the list because of its massive R&D expenditures and patent applications by non-residents.
[19] See Appendix B for list of countries with their order.

6.2 Model

6.2.1 Total Factor Productivity Model

This TFP model is implemented to identify the extent to which developing countries benefit from foreign technology, the diffusion mechanisms/channels involved, the factors that shape their absorption capabilities, and the sources of heterogeneity in the technology spillover gains by comparing them with each other.

The baseline model, Equation (1), is a modified version of Coe et al. (2009) and Seck (2009). In this case, international technology diffusion channels are capital goods import (indirect channel), inward FDI flows (indirect channel), and patent applications (direct channel). TFP is also dependent on human capital.

$$\boldsymbol{TFP_{it} = \alpha_i^0 + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^P \log S_{it}^P + \alpha^H \log H_{it} + \varepsilon_{it}} \qquad (1)$$

where $i=1,2 \ldots 46$ and $t=2000\text{-}2019$

$\boldsymbol{TFP_{it}}$ stands for the total factor productivity of country i at time t

$\boldsymbol{\alpha_i^0}$ is country-specific characteristics

$\boldsymbol{S_{i,t}^M = \sum_{j=1}^{7} \sigma_{ij,t}^M * S_{jt}^d}$ is the sum of the capital goods import-weighted foreign R&D stocks or G7 countries' domestic R&D stocks, and it is constructed to capture the R&D spillovers or technology diffusion through the import channel (for example, $S_{1,2000}^M$ is the G7 countries' weighted sum of domestic R&D where the weights are the capital goods import of Argentina with G7 countries in 2000)

$\boldsymbol{S_{i,t}^F = \sum_{j=1}^{7} \sigma_{ij,t}^F * S_{jt}^d}$ is the sum of the inward FDI flows weighted foreign R&D stocks or G7 countries' domestic R&D stocks, and it is constructed to capture the R&D spillovers or technology diffusion through the FDI channel (for example, $S^F_{1,2000}$ is the

G7 countries' weighted sum of domestic R&D where the weights are the inward FDI flows from G7 countries to Argentina in 2000)

$S_{i,t}^{P} = \sum_{j=1}^{7} \sigma_{ij,t}^{P} * S_{jt}^{d}$ *is the* sum of the patent-weighted foreign R&D stocks or G7 countries' domestic R&D stocks, and it is constructed to capture the R&D spillovers or technology diffusion through the patent channel (for example, $S_{1,2000}^{P}$ is the G7 countries' weighted sum of domestic R&D where the weights are the total patent applications from G7 countries to the patent offices in Argentina in 2000)

The weights are needed to show different international technology diffusion channels and how their effect on TFP changes depending on developing countries' varying import, FDI, and patent relationship volumes with G7 countries. These weights are constructed based on the idea of CH (1995).

- $\sigma_{ij,t}^{M} = \frac{M_{ij,t}}{Mit}$ - $\sigma_{ij,t}^{F} = \frac{FDI_{ij,t}}{FDIit}$ - $\sigma_{ij,t}^{P} = \frac{Pt_{ij,t}}{Pit}$

where *j= 1,2…7* G7 countries

M_{ijt} is the bilateral capital goods import from G7 country j to developing country i at time t (import composition of country i)

M_{it} *is* the total capital goods import from G7 countries to developing country i at time t

FDI_{ijt} *is* the bilateral inward FDI flows from G7 country j to developing country i at time t

FDI_{it} is the total bilateral inward FDI flows from G7 countries to developing country i at time t

Pt_{ijt} *is* the patent applications from G7 country j to developing country i at time t

$\boldsymbol{Pt_{it}}$ *is* the total patent applications from G7 countries to developing country i at time t

$\boldsymbol{H_{it}}$ *is* human capital (Index of human capital per person, based on years of schooling)

ε_{it} **is** a white noise disturbance term

G7 countries' R&D stocks are calculated using the perpetual inventory method, allowing depreciation.

$$S^d_{jt} = (1 - d)S^d_{j,t-1} + I^{RD}_{jt}$$

d is the depreciation rate of R&D stocks, which is taken as %20 based on Lee (2005) and Gonçalves, Taveira, Labrador, and Pio (2021)

I^{RD}_{jt} is the R&D expenditures in G7 country j at time t

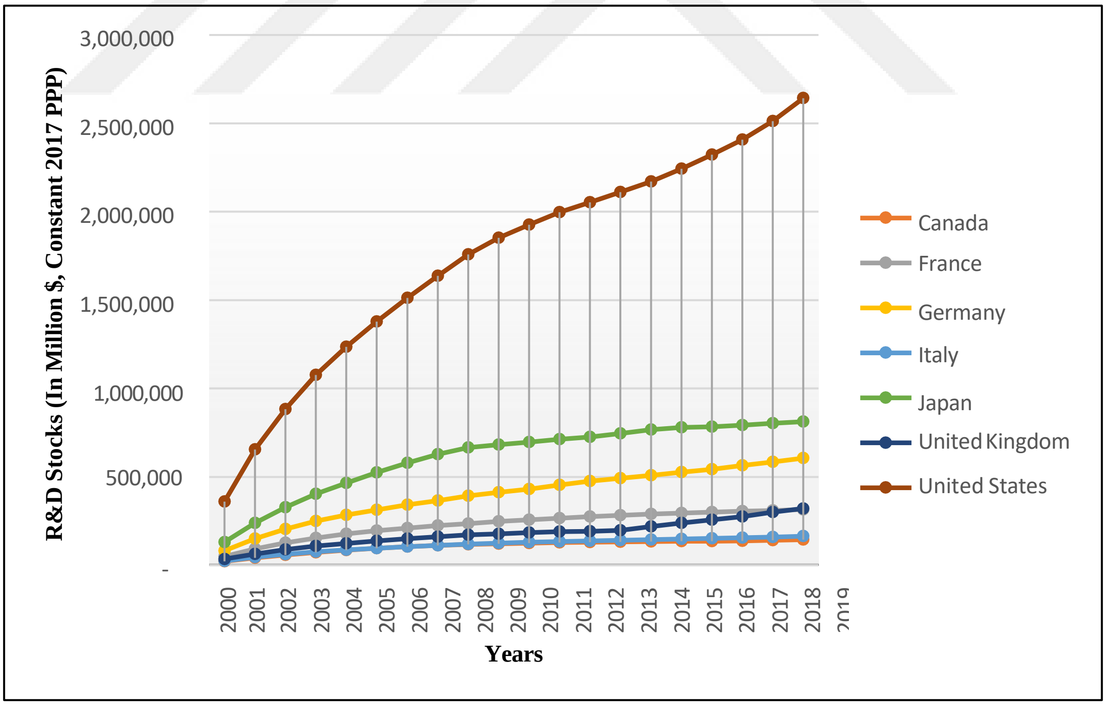

Figure 6.1 R&D Stocks of G7 Countries (2000-2019)

Source: Author's calculations based on OECD.Stat

Figure 6.1 illustrates the R&D stocks of the G7 countries from 2000 to 2019. It is evident that the United States possesses far more R&D stocks than other nations. Japan and Germany are emulating the United States, while Italy and Canada have the lowest level of innovative activity.

Table 6.2 presents a concise overview of the statistical data for the variables in Equation (1), Equation (2), and Equation (3) for developing countries in the sample. High-income nations exhibit the highest Total Factor Productivity (TFP) level among different income levels. Moreover, high-income countries also have the largest value in capital goods import volume with G7 countries, the sum of the capital goods import weighted foreign R&D stocks, trade openness, FDI inflows from G7 countries, FDI openness, patent applications by G7 countries, and patent openness. On the other hand, for FDI inflows weighted foreign R&D stocks, patent application weighted foreign R&D stocks, and human capital, upper middle-income countries have the highest values. Lower middle-income countries have the lowest values for all variables.

Table 6.2 Summary Statistics for Developing Countries[20]

Summary Statistics for Developing Countries				
Variable	**High Income**	**Upper Middle Income**	**Lower Middle Income**	**All Sample**
TFP (Av.)	6.8	4.1	3.4	14.3
M_{it} (Av.)	87,700	84,896	21,241	193,837
S^M_{it} (Av.)	23,098,985	17,832,483	8,688,043	49,619,510
MOP_{it} (Av.)	2.0	0.7	0.4	3.1
F_{it} (Av.)	40,392	34,402	9,107	83,901
S^F_{it} (Av.)	794,692	8,921,440	8,755,779	18,471,911
FOP_{it} (Av.)	0.12	0.04	-0.02	0.14
P_{it} (Av.)	54,849	47,071	20,485	122,404
S^P_{it} (Av.)	11,803,551	16,427,134	6,719,096	34,949,781
POP_{it} (Av.)	0.00397	0.00068	0.00010	0.005
$H_{i,t}$ (Av.)	146.9	180.3	93.3	420

Note: All values are the average of 2000-2019, and M_{it}, $S^M{}_{it}$, F_{it}, $S^F{}_{it}$, and $S^P{}_{it}$ variables are in millions.

[20] See Appendix B for detailed data of sample countries.

As mentioned before, one of the main aims of this thesis is to reveal the heterogeneity across developing countries in the process of technology spillovers. There are many country-specific factors that affect developing countries' ability to absorb technology from international technology diffusion. One of these factors is human capital. In addition to its direct effect on TFP, it has an indirect effect on TFP through its impact on technology diffusion because it is the one that can understand foreign high technology and absorb it for domestic use.

To assess human capital's role in the diffusion process, its interaction terms with diffusion channels, which are represented by S_{it}^{M}, S_{it}^{F}, S_{it}^{P} in the model, were added one by one. Then, the final equation below was estimated.

$$TFP_{it} = \alpha_i^0 + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^P \log S_{it}^P + \alpha^H \log H_{it} + \alpha^{MH} \log S_{it}^M * \log H_{it} + \alpha^{FH} \log S_{it}^F * \log H_{it} + \alpha^{PH} \log S_{it}^P * \log H_{it} + \varepsilon_{it} \tag{2}$$

where $i=1,2....46$ and $t=2000\text{-}2019$

Country openness (to trade, FDI, and patents) is another important factor affecting a country's absorption capacity. In light of this rationale, an examination of the interaction between foreign R&D spillovers and a country's degree of openness will be examined. This investigation aims to explore the potential advantage that more open countries may derive from capturing such spillovers.

The interaction terms of openness variables with diffusion channel weighted foreign R&D stocks were added to the model for estimation. Then, the final equation below was estimated.

$$TFP_{it} = \alpha_i^0 + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^P \log S_{it}^P + \alpha^H \log H_{it} + \alpha^{MO} \log S_{it}^M * \log MOP_{it} + \alpha^{FO} \log S_{it}^F * \log FOP_{it} + \alpha^{PO} \log S_{it}^P * \log POP_{it} + \alpha^{MOP} \log MOP_{it} + \alpha^{FOP} \log FOP_{it} + \alpha^{POP} \log POP_{it} + \varepsilon_{it} \tag{3}$$

MOP_{it} is the ratio of country i's total import from G7 countries to its real GDP at time t (to reflect trade openness)

$\boldsymbol{FOP_{it}}$ is the ratio of country i’s total FDI inflows from G7 countries to its real GDP at time t (to reflect FDI openness)

$\boldsymbol{POP_{it}}$ is the ratio of country i’s total patent applications from G7 countries to its population at time t (to reflect patent openness)

According to the data in table 6.2, high-income nations have the highest levels of trade openness, FDI openness, and patent openness, whereas lower middle-income countries have the lowest levels of these indicators.

The institutions are another factor that affects the extent to which countries benefit from foreign technology or the sources of heterogeneity in the spillover gains. Three indicators of the quality of the institutions are considered: the ease of doing business (EDB), the International Property Rights Index (IPRI), and the historical origin of the legal system[21].

The first institutional variable is EDB. The WB index, which assesses the ease of doing business, encompasses a wide range of factors that can impact economic decisions and the performance of domestic and international enterprises with current or potential connections to the economy. Introduced in 2003, the index serves as a thorough gauge of various jurisdictions that provide insights into government rules. It encompasses, among other things, the facilitation of cross-border trade, the safeguarding of investor rights, and the registration of property.

For the analysis, constructing this variable as a single-year dummy does not permit testing any potential direct impact on overall productivity within this panel data. Instead, only the conditional effect is taken into account.

$$TFP_{it} = \alpha_i^0 + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^P \log S_{it}^P + \alpha^H \log H_{it} + \alpha^{MEDB} \log S_{it}^M * DEDB_{it} + \alpha^{FEDB} \log S_{it}^F * DEDB_{it} + \alpha^{PEDB} \log S_{it}^P * DEDB_{it} + \varepsilon_{it} \quad (4)$$

[21] See Appendix B for more detailed institutional statistics of sample countries.

DEDB is a dummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019 and 0 otherwise.

The second institutional variable is represented by the IPRI, which assesses the strength of institutions related to property rights. These institutions encompass property rights, intellectual property rights, and legal and political environment. Therefore, this index can also show the heterogeneity across countries in international technology diffusion.

$$TFP_{it} = \alpha_i^0 + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^P \log S_{it}^P + \alpha^H \log H_{it} + \alpha^{MIPRI} \log S_{it}^M * DIPRI_{it} + \alpha^{FIPRI} \log S_{it}^F * DIPRI_{it} + \alpha^{PIPRI} \log S_{it}^P * DIPRI_{it} + \varepsilon_{it} \quad (5)$$

The IPRI scores are obtained from Levy-Carciente (2019)'s report of the International Property Rights Index 2019. DIPRI is a dummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019 and 0 otherwise.

The empirical data frequently indicates the superiority of the legal systems in common law countries (derived from British law) compared to civil law systems (derived from Roman law), especially those in French civil law countries. The Legal Origins Theory contrasts French civil law with British common law, asserting that the former is characterized by a greater degree of government ownership and regulation, which in turn increases the likelihood of negative impacts on markets. The British common law is linked to enhanced investor protection, reduced government ownership and regulation, and a less structured and more autonomous court system. These factors, in turn, contribute to more favorable economic results. The aforementioned attributes of the common law system create compelling motivations for foreign investments, resulting in significant economic benefits (La Porta et al., 2008).

For these reasons, the historical origin of the countries' legal system is considered a third institutional variable in this analysis. Moreover, the fact that most nations adhere to either the British or French legal systems[22] permits comparisons between the two, proving to be the most dissimilar approaches to laws and regulations.

[22] In the sample, only Bulgaria, Hong Kong, Hungary, Poland and Republic of Korea have German origin, other countries have either French or British origin.

To explore the potential role of the historical origin of the legal systems in explaining the heterogeneity in the absorption capabilities of technology spillovers by developing countries, a dummy variable (DLEGAL), which takes the value of 1 if British origin, was added into the model.

$$\boldsymbol{TFP_{it} = \alpha_i^{\,0} + \alpha^M \log S_{it}^{\,M} + \alpha^F \log S_{it}^{\,F} + \alpha^P \log S_{it}^{\,P} + \alpha^H \log H_{it} + \alpha^{MLEGAL} \log S_{it}^{\,M} * DLEGAL_{it} + \alpha^{FLEGAL} \log S_{it}^{\,F} * DLEGAL_{it} + \alpha^{PLEGAL} \log S_{it}^{\,P} * DLEGAL_{it} + \varepsilon_{it}} \qquad (6)$$

Table 6.3 Description of Main Variables of the TFP Model

Variable	Description	Expected Sign
TFP	Total Factor Productivity	
$\log S^M$	Log of foreign R&D stocks weighted by imports of capital goods	+/-
$\log S^F$	Log of foreign R&D stocks weighted by inward FDI flows	+/-
$\log S^P$	Log of foreign R&D stocks weighted by patent applications by non-residents	+
logH	Log of the index of human capital per person, based on years of schooling	+
logMOP	Log of trade openness	+/-
logFOP	Log of FDI openness	+/-
logPOP	Log of patent openness	+
DEDB	Dummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019, and 0 otherwise	+
DIPRI	Dummy variable that takes the value of 1 if the country if the country is ranked in in the top 60 in 2019, and 0 otherwise	+

Table 6.3 (continued)

DLEGAL	Dummy variable (DLEGAL), which takes the value of 1 if British origin, and 0 otherwise	+

6.2.1 Total Factor Productivity Convergence Model

This model aims to show how international technology diffusion affects the TFP convergence process. In other words, whether the developing countries, which prefer to imitate foreign technology rather than innovate, can catch up the countries at the technological frontier, in this case, G7 countries, and close the technology gap between these countries through the help of international technology diffusion. Moreover, another aim is to show how the speed of TFP convergence and the role of different technology diffusion channels in the convergence process vary depending on the different developing countries.

In this analysis, the type of convergence is conditional convergence of TFP because the TFP is under the impacts of technological spillovers.

The TFP convergence model, Equation (7), is the modified version of the baseline model, equation (1), and the modification was done based on Maryam and Jehan (2018). In this model, TFP growth is the dependent variable, and it depends on the capital goods import, inward FDI flows and patent application-related foreign R&D stocks, human capital, TFP gap, and the interaction terms of diffusion channels with the TFP gap.

$$TFPG_{it} = \alpha_i^0 + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^P \log S_{it}^P + \alpha^H \log H_{it} + \alpha^G (TFP_{it}/Avr.TFP_{jt}) + \alpha^{MG} \log S_{it}^M * (TFP_{it}/Avr.TFP_{jt}) + \alpha^{FG} \log S_{it}^F * (TFP_{it}/Avr.TFP_{jt}) + \alpha^{PG} \log S_{it}^P * (TFP_{it}/Avr.TFP_{jt}) + \varepsilon_{it} \quad (7)$$

where $i=1,2….46$ and $t=2000\text{-}2019$

$\boldsymbol{TFPG_{it}}$ stands for the TFP growth

$\boldsymbol{\alpha_i^0}$ is country-specific characteristics

$\boldsymbol{S^M_{it} = \sum_{j=1}^{7} \sigma^M_{ij,t} * S^d_{jt}}$ is the sum of the capital goods import-weighted foreign R&D stocks

$\boldsymbol{S^F_{it} = \sum_{j=1}^{7} \sigma^F_{ij,t} * S^d_{jt}}$ is the sum of the inward FDI flows weighted foreign R&D stocks

$\boldsymbol{S^P_{it} = \sum_{j=1}^{7} \sigma^P_{ij,t} * S^d_{jt}}$ *the* sum of the patent-weighted foreign R&D stocks

$\boldsymbol{H_{it}}$ human capital (Index of human capital per person, based on years of schooling)

$\boldsymbol{TFP_{it}/Avr.TFP_{jt}}$ is the TFP gap, which is the difference between the TFP of each non-frontier developing country in the sample from the average TFP of G7 countries. (In other words, it is the convergence or catch-up term)

$\boldsymbol{\alpha^G}$ is the speed of convergence or catch-up.

$\boldsymbol{logS_{it}^M * (TFP_{it}/Avr.TFP_{jt})}$ is the interaction term between the sum of the capital goods import weighted foreign R&D stocks and TFP gap (This variable shows how import-related foreign technology spillovers affect the process of convergence)

$\boldsymbol{logS_{it}^F * (TFP_{it}/Avr.TFP_{jt})}$ is the interaction term between the sum of the inward FDI flows weighted foreign R&D stocks and the TFP gap (This variable shows how FDI-related foreign technology spillovers affect the process of convergence)

$\boldsymbol{logS_{it}^P * (TFP_{it}/Avr.TFP_{jt})}$ is the interaction term between the sum of the patent-weighted foreign R&D and TFP gap (This variable shows how patent-related foreign technology spillovers affect the process of convergence)

$\boldsymbol{\varepsilon_{it}}$ ***is*** a white noise disturbance term

Table 6.4 TFP Growth in Developing Countries[23]

Years	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
2000	-0.08	-0.03	-0.09	-0.10
2001	-0.07	-0.06	-0.10	-0.04
2002	-0.06	-0.03	-0.07	-0.06
2003	0.00	0.02	0.01	-0.03
2004	0.03	0.06	0.03	0.01
2005	0.04	0.06	0.05	0.00
2006	0.03	0.03	0.02	0.02
2007	0.05	0.04	0.06	0.04
2008	0.01	0.02	0.01	0.00
2009	-0.11	-0.10	-0.12	-0.09
2010	0.04	0.04	0.07	-0.02
2011	0.01	0.03	0.03	-0.05
2012	-0.05	-0.05	-0.05	-0.04
2013	-0.04	0.00	-0.03	-0.08
2014	-0.07	-0.03	-0.08	-0.10
2015	-0.13	-0.09	-0.14	-0.15
2016	-0.08	-0.04	-0.09	-0.11
2017	-0.03	0.01	0.01	-0.13
2018	-0.05	0.00	-0.04	-0.13
2019	-0.07	-0.05	-0.07	-0.10

Note: All values are the average of the countries in the relevant group for that year.

Table 6.5 TFP Gap in Developing Countries

Years	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
2000	-0.45	-0.32	-0.56	-0.42
2001	-0.46	-0.32	-0.60	-0.42
2002	-0.54	-0.36	-0.67	-0.52
2003	-0.65	-0.47	-0.78	-0.66
2004	-0.73	-0.55	-0.86	-0.75
2005	-0.74	-0.55	-0.86	-0.76
2006	-0.76	-0.57	-0.88	-0.78
2007	-0.83	-0.64	-0.94	-0.85

[23] See Appendix B for detailed data of sample countries.

Table 6.5 (continued)

2008	-0.83	-0.65	-0.94	-0.85
2009	-0.74	-0.57	-0.85	-0.75
2010	-0.74	-0.56	-0.84	-0.77
2011	-0.79	-0.60	-0.88	-0.84
2012	-0.74	-0.56	-0.84	-0.79
2013	-0.76	-0.58	-0.86	-0.82
2014	-0.78	-0.60	-0.88	-0.84
2015	-0.68	-0.50	-0.78	-0.74
2016	-0.66	-0.48	-0.76	-0.72
2017	-0.68	-0.49	-0.77	-0.74
2018	-0.71	-0.53	-0.80	-0.78
2019	-0.68	-0.50	-0.77	-0.74

Note: All values are the average of the countries in the relevant group for that year. The TFP gap is the difference of the TFP of each non-frontier developing country in the sample from the average TFP of G7 countries.

Table 6.6 Description of Main Variables of the TFP Convergence Model

Variable	Description	Expected Sign
TFPG	Total Factor Productivity Growth	
$\log S^M$	Log of foreign R&D stocks weighted by imports of capital goods	+/-
$\log S^F$	Log of foreign R&D stocks weighted by inward FDI flows	+/-
$\log S^P$	Log of foreign R&D stocks weighted by patent applications by non-residents	+
logH	Log of index of human capital per person, based on years of schooling	+
(TFP/Avr.TFP)	TFP gap	-

Table 6.6 (continued)

$\log S^M * (TFP_{it}/Avr.TFP)$	Interaction term between log of the imports of capital goods weighted foreign R&D stocks with TFP gap	+/-
$\log S^F * (TFP/Avr.TFP)$	Interaction term between log of the inward FDI flows weighted foreign R&D stocks with TFP gap	+/-
$\log S^P * (TFP/Avr.TFP)$	Interaction term between log of the patent applications by non-residents weighted foreign R&D stocks with TFP gap	+/-

6.3 Data Sources[24]

TFP (at constant national prices, 2017=1) is obtained from Penn World Table 10.1, and TFP growth and TFP gap are based on the author's calculation.

The data on R&D expenditures (constant prices, PPP, 2015) is from the OECD Main Science and Technology Indicators dataset.

Bilateral import data and capital goods import data are from the OECD STAN database (Bilateral Trade by Industry and End-Use). Reporter countries are G7 countries, and 46 developing countries are taken as partners.

The data on bilateral FDI inflows is obtained from OECD FDI statistics according to Benchmark Definition 4th edition. Also, some missing variables are taken from the

[24] All variables in this analysis converted into constant US dollars (2017=1).

OECD Benchmark Definition 3rd edition as a complementary source. Reporter countries are G7 countries, and 46 developing countries are taken as partners.

Total patent application data, which includes direct and The Patent Cooperation Treaty (PCT) national phase entries, is from WIPO.

Human capital is the average years of formal education for individuals aged 15-64. This data is based on Barro and Lee (2015) and Lee and Lee (2016). The mean Years of Schooling data of the UNESCO Institute for Statistics (UIS) are complementary data.

GDP is output-side real GDP (at chained PPPs, 2017 US dollars), and population data are obtained from Penn World Table 10.1.

The Ease of Doing Business ranking data is obtained from WB's Doing Business archive.

The IPRI scores are obtained from Levy-Carciente (2019)'s report of the International Property Rights Index 2019.

The historical origin of the legal system of countries is based on the paper of (La Porta et al. (2008).

6.4 Methodology

Multiple methods exist for acquiring data sets for econometric investigations. Panel data refers to the combination of cross-sectional and time-series observations from various entities such as countries, firms, households, or individuals. This allows for the analysis of relationships by considering data series with cross-sectional and time dimensions that are not observable using cross-section and time series models (Baltagi, 2005). While the accessibility of the panel data approach has expanded across sectors, there is ongoing discussion on its distinct benefits and drawbacks.

The panel data method has two primary advantages as it integrates cross-sectional and time-series observations. Firstly, the larger number of observations allows the researcher to get more comprehensive information. Furthermore, it provides greater flexibility, enabling more accurate forecasts and the ability to analyze the individual impacts of unobservable units. Moreover, in contrast to cross-sectional analysis, the panel technique considers non-homogeneous differences across nations, businesses, families, and individuals and offers a modeling tool to evaluate these differences by horizontal or vertical cross-sectional analytic features. Also, due to the greater diversity and informativeness of panel data and the high degree of freedom in the estimated models, multicollinearity issues among variables are less prevalent and more efficiently managed (Baltagi, 1995).

The panel data study has the aforementioned benefits but presents certain difficulties. One of the primary drawbacks of utilizing panel data is the challenge of aggregating numbers from several units for the same variable and time period. Furthermore, when the time-series dimension is small- and the time dimension is shorter than the horizontal size, the explanatory capability of the fixed effects model diminishes (Hsiao, 2006).

Panel data analysis, especially short panel data, can be carried out using three distinct methods: pooled OLS (POLS) model, Fixed Effects (FE) model, and Random Effects (RE) model (Gujarati, 2003). This section showcases the various models and the process of choosing the most suitable one among them.

A. Pooled Ordinary Least Squares (POLS)

The estimation procedure of a pooled model is practically identical to that of a basic OLS model and utilizes the OLS methodology to analyze panel data. The common intercept in Equation (8), α, is assumed for all cross-sectional units in this estimation, which means that this technique does not consider the heterogeneity[25] between cross-sectional units. Therefore, it is believed that α is constant for all people, and there is no interdependence inside individual groups.

[25] Heterogeneity, in the context of economic theory and econometrics, pertains to variations among the entities under investigation.

Although the POLS approach is utilized in the estimations, recent studies in the literature have expressed concerns with this estimation method's disregard for the individual dimensions of panel data. Consensus among scholars indicates that this estimate strategy may yield inefficient and biased estimators.

$$Y_{it} = \alpha_{it} + \beta_i X_{it} + \varepsilon_{it} \qquad \text{where } t = 1, 2 \ldots T \; i = 1, 2 \ldots N \tag{8}$$

Y_{it} is the dependent variable,
α_{it} is an intercept term,
β_i is the slope coefficient,
X_{it} is an independent or explanatory variable,
ε_{it} is an error term,

B. Fixed Effects Model

This estimation method allows for the inclusion of cross-sectional heterogeneity by allowing the intercept, α_{it}, of the model to vary for each cross-sectional unit. Nevertheless, the slope coefficients remain constant across all cross sections, $\beta_{it} = \beta_k$ for all i and t. This technique highlights the distinct attributes of each entity.

Furthermore, FE is generally a more consistent estimator[26] even in the case of missing data in the cross-section dimension, but it is most suitable if the data covers the whole population of our cross-section dimension.

C. Random Effects Model

Additionally, there is an additional model that is also chosen to analyze the individual effects, which is the Random Effects (RE) model. RE models are applicable in situations where cross-sectional units are chosen randomly, and this model considers the cross-sectional heterogeneity by allowing the slope coefficients to vary across

[26] An estimator is considered consistent if it approaches the true value of a parameter as the sample size increases indefinitely.

different units. Within the context of this model estimation, it is presumed that the variance between cross-sectional units is random and uncorrelated with the predictor.

Changes are made to the RE models based on cross sections and/or by adding components to the error term, $\varepsilon_{it} + \mu_i$. While all cross-sections in fixed effect models have constant parameters that differ from one another, all cross-sections in random effects models have the same constant parameters (Bell et al., 2019).

An econometric test is available to determine if the FE model is better than the RE model. The test, known as the Hausman specification test, essentially examines the relationship between the variables and error terms. The model will be consistent with RE estimation if the null hypothesis of the Hausman tests, Ho: RE is valid/better, is not rejected. In this case, using RE is preferable because RE gives more consistent and more efficient estimates than FE.

Therefore, in this thesis, for both the TFP and TFP convergence models, the RE is generally used by always checking the Hausmann test results. In cases of rejection of the null hypothesis, models are estimated with FE.

CHAPTER VII

EMPRICAL ANALYSIS AND RESULTS

7.1 Results of Total Factor Productivity Model

The six equations represented in the previous chapter were estimated using short panel data, the data where time-series dimension is less than the cross-section dimension of annual observations, covering 46 developing countries for 20-year years (2000-2019). Therefore, whenever feasible, the RE estimation procedure was favored, and FE was used in case of the invalidity of RE.

The computations presented were performed using Gretl Version 2021c. The summary statistics of the variables in the regressions are presented in Appendix C with comprehensive information[27].

The symbols of the variables used in estimation equations are shown in Table 7.1.

Table 7.1 Symbols of the Variables in Gretl

Variable	Symbol
TFP	TFP
$\log S^M$	l_SM
$\log S^F$	l_SF
$\log S^P$	l_SP
logH	l_HC
$\log S^M * \log H$	SMH
$\log S^F * \log H$	SFH
$\log S^P * \log H$	SPH
logMOP	l_MOP
logFOP	l_FOP

[27] See Appendix C for descriptive summary statistics, like multicollinearity matrix, of all variables in the models.

Table 7.1 (continued)

logPOP	l_POP
$logS^M * logMOP$	SMOP
$logS^F * logFOP$	SFOP
$logS^P * logPOP$	SPOP
$logS^M * DEDB$	SMDEDB
$logS^F * DEDB$	SFDEDB
$logS^P * DEDB$	SPDEDB
$logS^M * DIPRI$	SMDIPRI
$logS^F * DIPRI$	SFDIPRI
$logS^P * DIPRI$	SPDIPRI
$logS^M * DLEGAL$	SMDLEGAL
$logS^F * DLEGAL$	SFDLEGAL
$logS^P * DLEGAL$	SPDLEGAL

A. Estimation of Baseline Model

The baseline model represented in Equation (1) was estimated for all 46 developing countries and income groups listed in Table 6.1.

$$TFP_{it} = \alpha_i^0 + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^P \log S_{it}^P + \alpha^H \log H_{it} + \varepsilon_{it} \qquad (1)$$

Table 7.2 shows the estimation results of the baseline model. For the import channel, it is significant only in lower middle-income developing countries, and it affects productivity positively. The inward FDI flows embodied foreign R&D stocks are an effective diffusion channel in high-income and upper middle-income countries, and it affects domestic productivity negatively; however, this channel is more effective in high-income countries.

According to the results, human capital and patent applications weighted foreign R&D stocks are significant for all sample and for all income groups; however, the significance level of patent channel is higher in high-income and lower middle-income countries and this international technology diffusion channel affects the TFP positively only in the high-income countries. The expected positive sign for human capital can be seen in upper middle and lower middle-income countries, but they are only significant at %90 level. The other two diffusion channels do not have clear effect on

TFP compared to the patent channel. This situation might suggest that direct channels are more powerful than the indirect channels in the process of international technology diffusion.

Table 7.2 Estimation Results of Model 1

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.942842*** (0.224165)	−2.54430*** (0.879294)	1.35679 (1.33387)	5.21241*** (0.975046)
l_SM	0.0147451 (0.0145640)	−0.0574591 (0.0477778)	−0.0289606 (0.0779067)	0.196894** (0.0825968)
l_SF	0.00374819 (0.00467203)	−0.0420795** (0.0163496)	−0.0408335* (0.0241384)	0.0325423 (0.0206004)
l_SP	−0.0272414** (0.0136571)	0.157306*** (0.0491987)	−0.164279** (0.0682049)	−0.439389*** (0.0845213)
l_HC	−0.167193** (0.0654906)	−0.553101** (0.263050)	0.687222* (0.365070)	0.474823* (0.253150)

Notes: The dependent variable is TFP; *, **, and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

B. The Role of Human Capital in International Technology Diffusion

To assess human capital's role in the diffusion process, its interaction terms with diffusion channels, which are represented by S_{it}^{M}, S_{it}^{F}, S_{it}^{P} in the model, were added one by one. Then, the final equation below was also estimated.

$$TFP_{it} = \alpha^{0} + \alpha^{M} \log S_{it}^{M} + \alpha^{F} \log S_{it}^{F} + \alpha^{P} \log S_{it}^{P} + \alpha^{H} \log H_{it} + \alpha^{MH} \log S_{it}^{M} * \log H_{it} + \alpha^{FH} \log S_{it}^{F} * \log H_{it} + \alpha^{PH} \log S_{it}^{P} * \log H_{it} + \varepsilon_{it} \quad (2)$$

Table 7.3 Estimation Results of Model 2

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	5.42988*** (1.64550)	−7.00916 (12.4224)	−1.77498 (11.7079)	3.52756 (13.1320)
l_SM	−0.149080** (0.0612599)	0.330376 (0.428120)	0.747368* (0.452365)	0.259986 (0.497355)
l_SF	0.00497380 (0.00466364)	−0.0409536** (0.0163449)	−0.0479073** (0.0243299)	0.0324728 (0.0207075)

Table 7.3 (continued)

l_SP	−0.0318869** (0.0136755)	0.157148*** (0.0490536)	−0.164614** (0.0677912)	−0.439941*** (0.0850398)
l_HC	−2.15992*** (0.726947)	4.45238 (5.49887)	9.52938* (5.08983)	1.36139 (6.89555)
SMH	0.0743426*** (0.0270113)	−0.172793 (0.189718)	−0.336177* (0.193012)	−0.0328406 (0.255254)

Notes: The dependent variable is TFP; *, **, and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

Firstly, the interaction term between human capital and capital goods import-weighted foreign R&D stocks was added to the model. It can be seen from Table 7.3 that for all sample, the effect of the import channel on TFP is significant but negative. This sign was also expected because, like in Bitzer and Geishecker (2006), the negative competition effect of imported goods can dominate the positive spillovers effects in the same sectors of developing countries.

However, the negative effect of import channel turned positive when it interacts with human capital (SMH), which means that foreign knowledge from imported goods becomes significant for TFP when human capital absorbs it for domestic use. This proves the indirect effect of human capital on domestic productivity through its impact on international technology spillovers.

Table 7.4 Estimation Results of Model 3

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	2.97718*** (0.955919)	6.82743*** (4.66865)	−2.67608 (5.23019)	−1.57481 (5.58886)
l_SM	0.0176997 (0.0145628)	−0.0616437 (0.0449312)	−0.0358993 (0.0792303)	0.174111** (0.0844327)
l_SF	−0.0730629** (0.0353919)	−0.806529*** (0.165457)	0.113933 (0.195588)	0.302579 (0.219928)
l_SP	−0.0307958** (0.0136920)	0.130247*** (0.0465755)	−0.161076** (0.0692538)	−0.432662*** (0.0844826)
l_HC	−1.08098** (0.422471)	−9.54589*** (1.95525)	2.52573 (2.33184)	4.12108 (2.96742)
SFH	0.0347981** (0.0158954)	0.336542*** (0.0725280)	−0.0688729 (0.0863787)	−0.136255 (0.110486)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

Table 7.4 shows the estimation results of the model in which only the interaction term between human capital and inward FDI-weighted foreign R&D stocks were included. The results are very similar to the Table 7.3. For all sample and high-income countries, the impact of inward FDI channel has a negative and statistically significant effect on TFP. These results can be reconciled with those of Javorcik (2004), which claims that MNEs and domestic firms in the same sectors compete and MNEs can prevent knowledge spillovers from taking place, and these negative horizontal spillovers (intra-industry spillovers) might suppress the possible positive effects from vertical spillovers (inter-industry spillovers). However, the negative effect turned positive when the human capital factor was considered (SFH). This result again shows the importance of human capital as an absorptive capacity for foreign technology.

Table 7.5 Estimation Results of Model 4

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	12.1569*** (1.90804)	17.4595*** (3.36094)	−1.48797 (1.54014)	−18.6155 (12.2872)
l_SM	0.0266487* (0.0142756)	−0.00227737 (0.0166418)	−0.00330984 (0.00950007)	0.154478* (0.0843591)
l_SF	0.00728502 (0.00457312)	0.000143290 (0.00575399)	0.000904468 (0.00293008)	0.0293714 (0.0203902)
l_SP	−0.464806*** (0.0751432)	−0.603578*** (0.125600)	0.0667963 (0.0599825)	0.474922 (0.477369)
l_HC	−5.04061*** (0.826243)	−7.38655*** (1.41336)	0.754679 (0.665432)	13.0581** (6.47361)
SPH	0.183823*** (0.0310731)	0.263197*** (0.0518213)	−0.0285087 (0.0250712)	−0.458726* (0.235821)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

Like SMH and SMF, SPH also transformed the negative international knowledge spillovers effect from patent applications into a positive one for all developing countries and high-income countries (See Table 7.5).

The estimation results of Model 5, which include all interaction terms of diffusion channels with human capital, cannot be evaluated because of the high correlation between the variables l_HC, SMH, SFH, and SPH (see Appendix C), which might result in serial multicollinearity problem.

Table 7.6 Estimation Results of Model 5

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	12.7231*** (1.95706)	6.19937 (4.78586)	−2.24238 (1.69620)	−0.551399 (12.5579)
l_SM	0.321432*** (0.100318)	0.470607*** (0.151171)	0.201196 (0.153557)	−3.89846*** (1.05934)
l_SF	0.0976739** (0.0465859)	−0.0273589 (0.0773165)	−0.0379446 (0.0357372)	0.329592 (0.255005)
l_SP	−0.873214*** (0.131580)	−0.667227*** (0.159596)	−0.0688903 (0.150109)	3.51211*** (0.968756)
l_HC	−5.17772*** (0.846069)	−2.33884 (2.08498)	1.07608 (0.727969)	3.78482 (6.58788)
SMH	−0.130117*** (0.0438546)	−0.210759*** (0.0668952)	−0.0865297 (0.0648643)	2.02385*** (0.527680)
SFH	−0.0403826* (0.0207675)	0.0128911 (0.0336305)	0.0168332 (0.0156024)	−0.154564 (0.128020)
SPH	0.360544*** (0.0561375)	0.289348*** (0.0667895)	0.0283596 (0.0632180)	−1.96165*** (0.480967)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

C. The Role of Country Openness in International Technology Diffusion

To be able to understand the role of country openness to trade, FDI, and patent, the openness terms (l_MOP, l_FOP, and l_POP) and their interactions with diffusion channels weighted foreign R&D stocks (SMOP, SFOP, and SPOP) added into the model one by one.

$$TFP_{it} = \alpha_i^0 + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^P \log S_{it}^P + \alpha^H \log H_{it} + \alpha^{MO} \log S_{it}^M * \log MOP_{it} + \alpha^{FO} \log S_{it}^F * \log FOP_{it} + \alpha^{PO} \log S_{it}^P * \log POP_{it} + \alpha^{MOP} \log MOP_{it} + \alpha^{FOP} \log FOP_{it} + \alpha^{POP} \log POP_{it} + \varepsilon_{it} \quad (3)$$

Table 7.7 shows the estimation results of the regression in which only the trade openness term and its interaction term were added to the baseline model. Trade openness is statistically significant at %99 level for all sample and upper middle-income countries, but it negatively impacts TFP. For example, %1 increase in trade openness will decrease the TFP by 0,02 units for whole sample. On the other hand, the SMOP variable is statistically significant and positive for all sample groups and the upper middle-income group, which means that trade openness is an important carrier of foreign knowledge through its impact on international knowledge spillovers. The more open countries in terms of trade can benefit more from foreign technology. However, the same result cannot be achieved for high-income and lower middle-income countries.

Table 7.7 Estimation Results of Model 6

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	−1.84966*** (0.573051)	−0.521466 (0.722795)	−2.16932 (2.75537)	−2.73001 (2.53670)
l_SM	0.0912430*** (0.0226009)	0.0273489 (0.0280942)	−0.0638625 (0.106832)	0.272156*** (0.0971891)
l_SF	0.00532075 (0.00436699)	−0.00373952 (0.00608911)	−0.0149917 (0.0157333)	0.0309389* (0.0169328)
l_SP	−0.00857755 (0.0129760)	0.0320369* (0.0186751)	−0.0881886* (0.0455801)	−0.270007*** (0.0742178)
l_HC	−0.259575*** (0.0621111)	−0.227483** (0.105487)	0.0623151 (0.273398)	0.484710** (0.207393)
l_MOP	−0.464398*** (0.150919)	−0.353976 (0.231672)	-1.85815*** (0.644137)	−0.784796 (0.566550)
SMOP	0.0133580** (0.00565542)	0.0132237 (0.00867593)	0.100433*** (0.0237432)	0.0176342 (0.0210548)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

Table 7.8 Estimation Results of Model 7

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	−0.845915 (0.571468)	−1.65316*** (0.558323)	0.479658 (0.439487)	3.39070 (3.13765)
l_SM	0.0152982 (0.0170576)	−0.0347351* (0.0183397)	0.00778306 (0.0109314)	0.195735* (0.103241)

Table 7.8 (continued)

l_SF	0.0758553*** (0.0202199)	0.0874085*** (0.0190550)	−0.0146755 (0.0153133)	0.117942 (0.0961326)
l_SP	−0.0314195** (0.0156494)	0.0337827* (0.0184661)	−0.00143323 (0.00911181)	−0.452493*** (0.0940394)
l_HC	−0.191675** (0.0745303)	−0.0879786 (0.0984246)	−0.0156368 (0.0534454)	0.468452* (0.277694)
l_FOP	−0.270879*** (0.0757131)	−0.385135*** (0.0779654)	0.0524149 (0.0564118)	−0.307090 (0.363508)
SFOP	0.0100717*** (0.00279504)	0.0144578*** (0.00282676)	−0.00194669 (0.00208385)	0.0117329 (0.0134852)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

Like in trade openness case, FDI openness (l_FOP) has also direct negative effect on domestic productivity in all sample and high-income countries (see Table 7.8); moreover, FDI openness's indirect effect on TFP (SFOP) is statistically significant and positive for these country groups. This shows that the countries which are more open to the activities of MNEs have advantage of benefitting from international technology diffusion compared to the less open countries.

For patent openness, the results of Model 8 claim that countries with more open to patent applications by non-residents might be affected negatively in terms of productivity, and this result is valid for all sample group and high-income country group. On the other hand, for these country groups, patent openness contributes to domestic productivity positively through its interaction with foreign R&D stocks (SPOP). Therefore, it can be said that patent openness is also a carrier for international knowledge spillovers, which means that countries that are more open to patents can absorb more foreign knowledge.

Table 7.9 Estimation Results of Model 8

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	−1.22019 (0.976802)	−3.90772*** (1.15123)	0.825569 (0.953775)	10.4808 (7.95804)
l_SM	0.0107878 (0.0150882)	−0.00754590 (0.0169390)	−0.000791304 (0.0112585)	0.117915 (0.0830773)

Table 7.9 (continued)

l_SF	0.00372112 (0.00464241)	−0.00137727 (0.00582218)	0.00141548 (0.00293404)	0.0417131** (0.0193284)
l_SP	0.0615926 (0.0415665)	0.183022*** (0.0439738)	−0.0244852 (0.0418827)	−0.497316 (0.318079)
l_HC	−0.194835*** (0.0661148)	−0.265670*** (0.0954893)	0.00432158 (0.0467077)	0.0820134 (0.256493)
l_POP	−0.201718** (0.0906230)	−0.496775*** (0.122886)	0.0514386 (0.0833543)	0.560176 (0.735116)
SPOP	0.00772618** (0.00331704)	0.0173154*** (0.00436526)	−0.00200958 (0.00306340)	−0.0170517 (0.0267261)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

Table 7.10 Estimation Results of Model 9

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	−2.49127** (1.01629)	−3.99507*** (1.14382)	−0.470816 (0.901676)	4.96178 (7.28656)
l_SM	0.0862400*** (0.0299392)	−0.0519330* (0.0304510)	−0.00404632 (0.0241237)	0.257065** (0.126613)
l_SF	0.0500196** (0.0199377)	0.0764201*** (0.0194328)	−0.0249640* (0.0140190)	−0.00675977 (0.0788897)
l_SP	−0.0196757 (0.0477966)	0.145532*** (0.0499979)	0.0490613 (0.0433921)	−0.429813 (0.301896)
l_HC	−0.280103*** (0.0710877)	−0.115380 (0.106851)	−0.0876470 (0.0534942)	0.0988963 (0.223873)
l_MOP	−0.445015** (0.194355)	0.193376 (0.258682)	0.0576029 (0.131766)	−1.43099** (0.685468)
l_FOP	−0.162161** (0.0758172)	−0.319831*** (0.0817913)	0.102982** (0.0520532)	0.200450 (0.299815)
l_POP	0.0330874 (0.110443)	−0.378649** (0.148859)	−0.0767891 (0.0897306)	0.789881 (0.695156)
SMOP	0.0122693* (0.00721318)	−0.00673578 (0.00960084)	−0.00469526 (0.00485215)	0.0428356* (0.0255624)
SFOP	0.00630249** (0.00278592)	0.0121157*** (0.00296247)	−0.00358282* (0.00191623)	−0.00666728 (0.0110763)
SPOP	−0.000974393 (0.00402443)	0.0132446** (0.00530015)	0.00240866 (0.00328774)	−0.0260599 (0.0252957)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

The estimation results of Model 9, which include all interaction terms of diffusion channels with openness terms, cannot be evaluated because of the high correlation between the variables (see Appendix C), which might result in serial multicollinearity problem.

D. The Role of Institutions in International Technology Diffusion

D.1 Ease of Doing Business (EDB)

Table 7.11 shows the estimation results of the regression in which the interaction term of capital goods imports embodied foreign R&D stocks with DEDB is added to the baseline model. Except upper middle-income countries, for all other groups, this term is statistically significant, and it positively impacts TFP in high-income countries and all sample group. This shows that a developing country that offers a more conducive institutional setting also reaps the most advantages from technological spillovers through import channel.

Table 7.11 Estimation Results of Model 10

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.785104*** (0.234769)	−3.16764*** (0.647532)	1.45488 (1.34738)	7.55981*** (0.794298)
l_SM	0.0236994 (0.0151002)	−0.177681*** (0.0586287)	−0.0424085 (0.0787658)	0.0508682 (0.0654164)
l_SF	0.00363001 (0.00466103)	−0.0367271** (0.0157963)	−0.0399467* (0.0240894)	0.0281862* (0.0157605)
l_SP	−0.0260747* (0.0136328)	0.120760** (0.0482467)	−0.168344** (0.0681414)	−0.213028*** (0.0698187)
l_HC	−0.168682*** (0.0653131)	−0.438074* (0.254589)	0.666109* (0.364809)	0.517150*** (0.193636)
SMDEDB	1.43128e-05** (6.58908e-06)	0.189706*** (0.0553239)	0.0502545 (0.0471233)	0.576818*** (0.0673053)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DEDB is a dummy variable that take the value of 1 if the country is ranked in the top 60 in 2019, and 0 otherwise.

Table 7.12 Estimation Results of Model 11

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.562464 (0.707490)	−3.31115*** (0.631368)	1.35854 (1.34499)	6.01868*** (0.923919)
l_SM	0.0172600 (0.0500546)	−0.0609145 (0.0448675)	−0.0287467 (0.0779480)	0.118482 (0.0787993)
l_SF	−0.0514438*** (0.0186955)	−0.108317*** (0.0207871)	−0.0430140 (0.0265850)	0.0651477*** (0.0206081)
l_SP	−0.110655** (0.0469830)	0.118652** (0.0466343)	−0.164464** (0.0682260)	−0.381607*** (0.0795424)
l_HC	−0.122794 (0.227433)	−0.264600 (0.252407)	0.688210* (0.365322)	0.486137** (0.234676)
SFDEDB	0.0596939** (0.0271121)	0.122921*** (0.0261753)	0.00672163 (0.0344187)	0.148200*** (0.0352194)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DEDB is a dummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019 and 0 otherwise.

Table 7.12 shows the estimation results of the regression in which the interaction term of inward FDI flows embodied foreign R&D stocks with DEDB is added to the baseline model. The results are very similar to the Table 7.11. Except for upper middle-income countries, for all other groups, this term is statistically significant and has a positive impact on TFP. This shows that a developing country that offers a more conducive institutional setting is also the one that reaps the most advantages from technological spillovers through the FDI channel.

From Table 7.13, it can be said that the variable SPDEDB is significant in all sample group. This shows that the developing countries, which have a higher ranking in EDB, benefit more from technology spillovers through patent channel. In addition to the whole sample, the same result also applies to high-income countries.

The estimation results of Model 13, which includes all interaction terms of diffusion channels with DEDB, cannot be evaluated because of the high correlation between the variables (see Appendix C).

Table 7.13 Estimation Results of Model 12

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.781520 (0.823573)	−3.16201*** (0.596118)	1.38334 (1.34879)	7.93610*** (2.21375)
l_SM	0.0163719 (0.0495924)	−0.0497430 (0.0426193)	−0.0287228 (0.0779406)	0.217993 (0.211653)
l_SF	−0.0273786* (0.0158346)	−0.0263392* (0.0147286)	−0.0405623* (0.0241609)	0.0379363 (0.0461960)
l_SP	−0.132619*** (0.0491761)	−0.147229** (0.0634290)	−0.169048** (0.0705013)	−0.584777** (0.230755)
l_HC	−0.185670 (0.223213)	−0.0990815 (0.243008)	0.682872* (0.365526)	−0.00503428 (0.566949)
SPDEDB	0.0565426** (0.0259159)	0.313859*** (0.0481949)	0.0122349 (0.0456182)	−0.152040 (0.146363)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DEDB is a dummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019, and 0 otherwise.

Table 7.14 Estimation Results of Model 13

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.791926*** (0.236846)	0.371459 (0.230189)	1.41783 (1.35331)	5.36832*** (2.35210)
l_SM	0.0235595 (0.0151808)	0.0713085** (0.0285802)	−0.144206 (0.0881974)	0.592462** (0.227260)
l_SF	0.00458478 (0.00602980)	0.000476461 (0.00884798)	−0.0277246 (0.0294520)	0.0292555 (0.0501531)
l_SP	−0.0269661* (0.0146759)	−0.129981*** (0.0332559)	−0.0701265 (0.0805667)	−0.919083*** (0.241304)
l_HC	−0.170038*** (0.0657308)	−0.00807722 (0.0954630)	0.613797* (0.362535)	−0.116415 (0.540284)
SMDEDB	1.42358e-05** (6.63509e-06)	−0.113481*** (0.0353352)	0.409064*** (0.152709)	−1.72540*** (0.489518)
SFDEDB	−0.00238136 (0.00945859)	0.00253242 (0.0114832)	−0.0407645 (0.0505665)	0.0961707 (0.104814)
SPDEDB	0.00216065 (0.0108243)	0.183533*** (0.0359340)	−0.323276** (0.141231)	0.924700*** (0.338096)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DEDB is a dummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019, and 0 otherwise.

D.2 International Property Rights Index (IPRI)

The variable SMDIPRI is positive and significant at %90 level for all developing countries in the sample. This claims that countries that better protect intellectual property rights get more out of technology spillovers embodied in capital goods import than other countries. Moreover, this result also holds among lower middle-income countries.

Table 7.15 Estimation Results of Model 14

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.951915*** (0.224015)	−2.61081*** (0.897027)	1.33001 (1.34286)	4.30466*** (1.00480)
l_SM	0.0105645 (0.0147145)	−0.0213273 (0.0655576)	−0.0315208 (0.0785904)	0.162460** (0.0811937)
l_SF	0.00400940 (0.00466016)	−0.0434401*** (0.0163962)	−0.0409904* (0.0241748)	0.0370646* (0.0200679)
l_SP	−0.0279339** (0.0136230)	0.158667*** (0.0491369)	−0.164386** (0.0682924)	−0.412073*** (0.0826728)
l_HC	−0.167748** (0.0653169)	−0.541713** (0.262651)	0.691311* (0.365904)	0.211942 (0.264441)
SMDIPRI	0.0104441* (0.00587596)	−0.0404358 (0.0508174)	0.0138961 (0.0511743)	0.190110*** (0.0706361)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DIPRI is adummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019, and 0 otherwise.

Table 7.16 Estimation Results of Model 15

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.591367 (0.816631)	−2.54628*** (0.892842)	1.36120 (1.34041)	6.18238*** (2.17402)
l_SM	0.0209211 (0.0499588)	−0.0636449 (0.0481801)	−0.0288167 (0.0780244)	0.306233* (0.179385)
l_SF	−0.0437849** (0.0177356)	−0.0129506 (0.0359607)	−0.0399047 (0.0253753)	0.0235213 (0.0451949)
l_SP	−0.106208** (0.0467804)	0.160999*** (0.0492710)	−0.164150** (0.0683027)	−0.672557*** (0.184334)
l_HC	−0.192422 (0.223833)	−0.535823** (0.262775)	0.684681* (0.366134)	−0.532066 (0.578725)

Tablo 7.16 (continued)

SFDIPRI	0.0361891* (0.0201817)	−0.0327215 (0.0360002)	−0.00460605 (0.0382348)	0.252239*** (0.0928288)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DIPRI is a dummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019, and 0 otherwise.

Table 7.17 Estimation Results of Model 16

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.838979*** (0.204381)	−2.60802*** (0.900209)	1.33969 (1.34625)	3.90334*** (1.00946)
l_SM	0.0168832 (0.0144979)	−0.0597416 (0.0479031)	−0.0295019 (0.0781517)	0.184293** (0.0788718)
l_SF	0.00362887 (0.00459931)	−0.0428917*** (0.0163746)	−0.0409289* (0.0241821)	0.0386965* (0.0197353)
l_SP	−0.0553693*** (0.0149690)	0.188700*** (0.0724975)	−0.164695** (0.0683807)	−0.415046*** (0.0809466)
l_HC	−0.171203*** (0.0653974)	−0.545056** (0.262758)	0.687829* (0.365661)	0.00854231 (0.279022)
SPDIPRI	0.0582887*** (0.0133680)	−0.0311523 (0.0521035)	0.00642007 (0.0513570)	0.216962*** (0.0650635)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DIPRI is a dummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019, and 0 otherwise.

Table 7.18 Estimation Results of Model 17

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.862382*** (0.205006)	0.532420** (0.243046)	0.310118** (0.142025)	3.68643*** (1.01920)
l_SM	0.0271591 (0.0193504)	0.375645*** (0.122886)	−0.00592336 (0.0100886)	0.218646** (0.0845002)
l_SF	0.00627034 (0.00603374)	0.0178237 (0.0251350)	0.000583460 (0.00322497)	0.0426676** (0.0208008)
l_SP	−0.0647700*** (0.0169206)	−0.499564*** (0.127531)	0.00444634 (0.00845011)	−0.428800*** (0.0814584)
l_HC	−0.185893*** (0.0665684)	−0.203931** (0.0938832)	0.00951346 (0.0447482)	−0.150944 (0.302911)
SMDIPRI	−0.0297706 (0.0298572)	−0.383942*** (0.124127)	0.0653270** (0.0318341)	−0.263515 (0.237072)

Table 7.18 (continued)

SFDIPRI	−0.00853696 (0.00948271)	−0.0236127 (0.0258656)	0.00665074 (0.00748754)	−0.0341759 (0.0643074)
SPDIPRI	0.0898781*** (0.0274358)	0.533734*** (0.128143)	−0.0905834*** (0.0346801)	0.491894** (0.208631)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DIPRI is a dummy variable that takes the value of 1 if the country is ranked in the top 60 in 2019, and 0 otherwise.

As with the import channel, productivity in developing countries with high IPRI rankings is more affected by knowledge spillovers from inward FDI and patent channels (see Table 7.16 and 7.17).

The estimation results of Model 17, which includes all interaction terms of diffusion channels with DIPRI, cannot be evaluated because of the high correlation between the variables (see Appendix C).

D.3 Origin of Legal System

Table 7.19 shows how origin of legal system affects the productivity gains from capital goods import embodied foreign knowledge spillovers. According to the results, for sample developing countries, SMDLEGAL is statistically significant at %99 level. This means that countries with British legal origins generally seem to gain more from technology spillovers via the import channel. This is also true among high-income countries, but for other country groups, legal of origin is not important absorption factor for international technology diffusion.

From Table 7.20, it is clear that the legal system's origin also has a positive effect on the knowledge spillovers from inward FDI flows for 46 developing countries.

Moreover, based on the estimation findings of model 20, SPDLEGAL exhibits statistical significance with a confidence level of 99%, which shows that countries with British legal origins tend to benefit more from technology spillovers through patent channel. This phenomenon is also observed in lower middle-income nations. However, for other groupings of countries, the legal origin does not play a significant role in facilitating the international diffusion of technology.

Table 7.19 Estimation Results of Model 18

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.740922*** (0.210568)	−2.78320*** (0.885365)	1.21049 (1.16332)	4.85908 (0.970015)
l_SM	0.00823633 (0.0148226)	−0.0750229 (0.0483300)	−0.0433236 (0.0787296)	0.163648 (0.0824294)
l_SF	0.00467439 (0.00465705)	−0.0407941** (0.0162370)	−0.0382186* (0.0241662)	0.0342835 (0.0202310)
l_SP	−0.0253164* (0.0136649)	0.169374*** (0.0492473)	−0.166364** (0.0683196)	−0.417220 (0.0835434)
l_HC	−0.234455*** (0.0697103)	−0.692730** (0.271478)	0.447470* (0.383420)	0.324317 (0.257527)
SMDLEGAL	0.0606945*** (0.0202448)	0.0676625* (0.0359845)	0.255600 (0.119633)	0.154757 (0.0697824)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DLEGAL is a dummy variable that takes the value of 1 if British origin, and 0 otherwise.

Table 7.20 Estimation Results of Model 19

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.817075 (0.815118)	−2.59480*** (0.890307)	1.31754 (1.34824)	5.12413*** (0.973779)
l_SM	0.0314494 (0.0498073)	−0.0526140 (0.0487558)	−0.0277773 (0.0780072)	0.178598** (0.0834506)
l_SF	−0.0377662** (0.0159813)	−0.0463142** (0.0184069)	−0.0432365* (0.0250808)	0.0299717 (0.0206171)
l_SP	−0.0986853** (0.0462009)	0.157408*** (0.0492536)	−0.164399** (0.0682192)	−0.422330*** (0.0851953)
l_HC	−0.558459** (0.251805)	−0.594338** (0.276316)	0.683964* (0.365336)	0.399222 (0.258625)
SFDLEGAL	0.0226681*** (0.00728634)	0.0128531 (0.0255798)	0.0150880 (0.0428056)	0.0575300 (0.0435071)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DLEGAL is a dummy variable that takes the value of 1 if British origin, and 0 otherwise.

Table 7.21 Estimation Results of Model 20

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.734387*** (0.208746)	−2.66853*** (0.888392)	1.24117 (1.34746)	4.84088*** (0.948715)

Table 7.21 (continued)

l_SM	0.0209578 (0.0146611)	−0.0520089 (0.0479212)	−0.0282567 (0.0777989)	0.182309** (0.0798068)
l_SF	0.00368779 (0.00462584)	−0.0425919*** (0.0163254)	−0.0404691* (0.0240980)	0.0362891* (0.0199069)
l_SP	−0.0360443*** (0.0138071)	0.152185*** (0.0493020)	−0.168072** (0.0681999)	−0.441073*** (0.0815109)
l_HC	−0.257174*** (0.0703007)	−0.665728** (0.280492)	0.636400* (0.368182)	0.293719 (0.251749)
SPDLEGAL	0.0656789*** (0.0181771)	0.0396311 (0.0344741)	0.0550487 (0.0561946)	0.182212*** (0.0618515)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DLEGAL is a dummy variable that takes the value of 1 if British origin, and 0 otherwise.

Table 7.22 Estimation Results of Model 21

Variable	*All Sample*	High Income	Upper Middle-Income	Lower Middle-Income
const	0.812042 (0.832152)	0.326717 (0.252892)	1.37062 (1.35758)	4.94000*** (0.966632)
l_SM	0.00802402 (0.0549039)	0.00180852 (0.0224512)	−0.0715832 (0.0788065)	0.226549*** (0.0853313)
l_SF	−0.0361328** (0.0163503)	−0.00289189 (0.00741414)	−0.0287972 (0.0261226)	0.0405595* (0.0204494)
l_SP	−0.0791794 (0.0502265)	0.0192905 (0.0213119)	−0.135109* (0.0690093)	−0.489599*** (0.0869668)
l_HC	−0.549616** (0.261898)	−0.336001*** (0.118040)	0.529244 (0.368363)	0.331924 (0.252316)
SMDLEGAL	0.120654 (0.117120)	−0.00222958 (0.0394095)	0.702015** (0.287599)	−0.237666 (0.274687)
SFDLEGAL	0.0236394** (0.0108964)	−0.00579844 (0.0134767)	−0.0637274 (0.0645708)	−0.0410879 (0.0874003)
SPDLEGAL	−0.115860 (0.121630)	0.0506767 (0.0367041)	−0.556885** (0.279974)	0.430650** (0.193792)

Notes: The dependent variable is TFP; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients. DLEGAL is a dummy variable that takes the value of 1 if British origin, and 0 otherwise.

The estimation results of Model 21, which includes all interaction terms of diffusion channels with DLEGAL, cannot be evaluated because of the high correlation between the variables (see Appendix C).

Summary of Estimation Results

Since one of the main aims of this thesis is to compare developing countries' ability to absorb foreign knowledge from technology diffusion and the relative importance of different diffusion channels in that they are involved, in this part, the estimation results were gathered to give a general assessment of the estimation results.

As shown in Table 7.2, for high-income countries, the most powerful diffusion channel is the patent channel, which is significant at %99 level and impacts TFP positively, as expected. The inward FDI flows channel is also effective in the process of foreign knowledge spillovers in these countries; however, its impact on domestic productivity is negative and weaker. As mentioned, the negativity of FDI-related knowledge spillovers may arise from the competition between MNEs and domestic firms. Despite the FDI and patent channels, capital goods import is not an effective means of international technology diffusion.

In the case of upper middle-income countries, patent applications by non-residents are the most effective means of technology diffusion. However, it is worth noting that the coefficient associated with this channel has a negative value, which goes against the expected sign seen in existing literature. FDI also diffuses technology in these nations, but its statistical significance level is modest and has a detrimental effect. In addition, similar to high-income countries, the import channel is inefficient. Furthermore, high-income and upper middle-income nations exhibit similarities in the relative importance of diffusion channels.

In lower middle-income countries, the patent channel and import channel have a significant impact on TFP. Although the import channel has a positive impact, the patent channel has a negative impact and is more influential in these countries.

The indirect role of human capital in international technology diffusion varies depending on the developing country classification and diffusion channels (see Table 7.3, 7.4 and 7.5). The variable SMH, which shows how human capital affects the foreign knowledge spillovers from the import channel, is effective and positive in the whole sample. This means that human capital is a crucial factor in absorbing import-embodied foreign knowledge and affects TFP indirectly. However, for high, upper-middle, and lower middle-income country groups, human capital does not have a significant indirect effect on domestic productivity. Therefore, it can be said that human capital cannot be a country-specific factor to distinguish the developing countries for import channel.

The interaction between inward FDI flows and human capital (SFH) is once again found to be substantial and positively impacts TFP across the entire sample. The negativity of foreign knowledge spillovers from FDI (l_SF) on domestic productivity becomes positive when these spillovers are processed by human capital. Furthermore, the presence of this interaction term is statistically significant in high-income nations but not in the other two developing country groups. Thus, it may be asserted that high-income nations can differentiate themselves from upper middle and lower middle-income countries by virtue of human capital's indirect influence on TFP through its effect on FDI-related knowledge spillovers.

Similar to the other two channels, the influence of human capital on TFP through the patent channel (SPH) is similarly positive and significant for the entire sample. Moreover, like in the FDI channel, this factor is a distinctive absorptive capacity factor for only high-income developing country group.

Country openness to trade, FDI, and patent, another country-specific factor for international technology diffusion, has a favorable influence on TFP for the entire sample through its impact on all diffusion channels (SMOP, SFOP, and SPOP). This suggests that the developing countries with higher import volumes with the G7 and higher FDI inflows and patent applications from the G7 can contribute more to their TFP through foreign technology diffusion. However, when looking at developing country groups in detail (see Table 7.7, 7.8, and 7.9), while trade openness is only effective absorptive factor in upper middle-income developing countries, FDI and patent openness are only effective in high-income developing countries.

In the process of international knowledge diffusion, EDB is another possible heterogeneity factor across countries, and this factor also affects positively domestic productivity of developing countries via its interaction with all diffusion channels (SMDEDB, SFDEDB and SPDEDB) for the whole sample. For detailed developing country groups, more conducive institutional settings allow high-income and lower middle-income countries to benefit more from capital goods import and FDI inflows embodied foreign knowledge; however, patent embodied knowledge spillovers benefit only high-income countries.

The protection of intellectual property rights, proxied by IPRI, is a positive determinant for drawing foreign knowledge through import, FDI, and patent channels for developing countries in the sample (see Table 7.15, 7.16, and 7.17). However, for countries with a higher ranking in IPRI in the lower middle-income group only, the international knowledge spillovers affect TFP through all channels. For high-income and upper middle-income countries, no effect of IPRI is observed.

The last heterogeneity effect across developing countries is the origin of the legal system, and, in the developing countries, which have a British-originated legal system, the foreign knowledge spillovers from all channels in this analysis contribute positively to the TFP. Furthermore, only in lower middle-income countries and for patent channel origin of the legal system plays a role in facilitating international technology diffusion.

7.2 Results of Total Factor Productivity Convergence Model

The TFP convergence model, Equation (7), was estimated with FE estimation procedure for 46 developing countries from 2000 to 2019. However, like in TFP regressions, because of the high correlation between interaction terms and TFP gap term, estimation was made in four different stages for all groups. The computations presented were performed using Gretl Version 2021c. The summary statistics of the variables in the regressions are presented in Appendix C with comprehensive information[28].

[28] See Appendix C for descriptive summary statistics, like multicollinearity matrix, of all variables in the models.

$$TFPG_{it} = \alpha^{0} + \alpha^{M} \log S_{it}^{M} + \alpha^{F} \log S_{it}^{F} + \alpha^{P} \log S_{it}^{P} + \alpha^{H} \log H_{it} + \alpha^{G} (TFP_{it}/Avr.TFP_{jt}) + \alpha^{MG} \log S_{it}^{M} * (TFP_{it}/Avr.TFP_{jt}) + \alpha^{FG} \log S_{it}^{F} * (TFP_{it}/Avr.TFP_{jt}) + \alpha^{PG} \log S_{it}^{P} * (TFP_{it}/Avr.TFP_{jt}) + \varepsilon_{it} \quad (7)$$

The symbols of the variables used in estimation equations are shown in Table 7.23.

Table 7.23 Symbols of the Variables in Gretl

Variable	Symbol
TFPG	TFPG
$\log S^{M}$	l_SM
$\log S^{F}$	l_SF
$\log S^{P}$	l_SP
logH	l_HC
TFP/Avr.TFP	TFPGAP
$\log S^{M}$ * (TFP/Avr.TFP)	SMGAP
$\log S^{F}$ * (TFP/Avr.TFP)	SFGAP
$\log S^{P}$ * (TFP/Avr.TFP)	SPGAP

From Table 7.24, it is clear that the TFP gap is statistically highly significant, and it has negative coefficients for all sample. This means that the greater the distance of a country from the frontier, the higher the TFP growth will be, resulting in a faster speed of convergence.

When looking at the income-based developing country groups, the TFP gap term is statistically significant and negative in all groups; however, the significance level is only %90 in lower middle-income countries. Furthermore, while convergence speed is highest in lower middle-income countries, it is the lowest in upper middle-income countries.

Table 7.24 Estimation Results of Model 1

Variable	All Sample	High Income	Upper Middle-Income	Lower Middle-Income
const	4.11798*** (1.24384)	0.209340 (0.248587)	0.708081 (1.22417)	0.785141 (0.688902)
l_SM	0.273741*** (0.0880844)	−0.00768915 (0.0174337)	0.118364 (0.0791997)	−0.0234827 (0.218555)
l_SF	−0.00412294 (0.0158033)	−0.00414908 (0.00593586)	−0.0419242 (0.0258730)	−0.0217542 (0.0402081)

Table 7.24 (continued)

l_SP	0.431701*** (0.105379)	0.0381419** (0.0182509)	−0.191267*** (0.0674140)	−0.482344** (0.213906)
l_HC	0.890393 (0.710655)	−0.202440** (0.0957757)	−0.126085 (0.368499)	0.738073 (0.556678)
TFPGAP	−0.212703*** (0.0395884)	−0.332214*** (0.0689560)	−0.184219*** (0.0561824)	−0.750359* (0.418750)

Notes: The dependent variable is TFPG; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

Table 7.25 Estimation Results of Model 2

Variable	All Sample	High Income	Upper Middle-Income	Lower Middle-Income
const	4.11801*** (1.27377)	0.112931 (0.255364)	−0.409638 (0.329087)	1.10582*** (0.331574)
l_SM	0.274062*** (0.0881918)	0.0340320 (0.0268753)	0.0789413*** (0.0207580)	0.0497164 (0.222636)
l_SF	0.00411355 (0.0158131)	−0.00452843 (0.00592531)	0.00961311 (0.00671863)	−0.0216119 (0.0402425)
l_SP	−0.432454*** (0.105426)	0.0389061** (0.0182395)	−0.0277047 (0.0175067)	−0.475927** (0.213857)
l_HC	0.895447 (0.711026)	−0.198987** (0.0956192)	−0.275306*** (0.0957091)	0.722272 (0.554879)
SMGAP	−0.00785166*** (0.00146983)	−0.0116223*** (0.00248493)	−0.00699198*** (0.00212272)	−0.0272493* (0.0154520)

Notes: The dependent variable is TFPG; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

The interaction term between import-embodied foreign knowledge spillovers is statistically significant for all sample and income-based developing country groups (see Table 7.25). Contrary to the positive direct effect of import-embodied foreign knowledge spillovers (l_SM) on TFP growth, the negativity of the coefficients of its interaction with TFP proves that import triggers the convergence of TFP as a channel for international technology diffusion.

SFGAP term and SPGAP term are statistically significant at %99 level and negative in all sample group (see Table 7.26 and Table 7.27), which suggests that rising FDI inflows or patent applications by non-residents initiate the catch-up process and help developing countries achieve higher TFPG mostly as a result of acquiring advanced foreign technology. Also, in high-income and upper middle-income countries, FDI and patent applications positively affect the TFP convergence process as a channel for international technology spillovers.

Table 7.26 Estimation Results of Model 3

Variable	All Sample	High Income	Upper Middle-Income	Lower Middle-Income
const	−0.103399 (0.195708)	−2.80161*** (0.693349)	−0.388052 (0.327498)	1.08300*** (0.326600)
l_SM	0.0318894** (0.0128732)	−0.0510428 (0.0477816)	0.0641476*** (0.0205251)	0.0400785 (0.0294532)
l_SF	0.0148675*** (0.00415744)	0.0433553*** (0.0163410)	0.0255088*** (0.00683347)	0.000322623 (0.00564606)
l_SP	−0.00658523 (0.0120536)	0.144081*** (0.0502595)	−0.0297495* (0.0174447)	−0.0712316** (0.0285570)
l_HC	−0.205920*** (0.0578663)	−0.522674** (0.261965)	−0.272513*** (0.0954753)	0.0132746 (0.0729876)
SFGAP	−0.00755713*** (0.00146223)	−0.0114902*** (0.00248387)	−0.00651222*** (0.00212353)	0.00125750 (0.00198729)

Notes: The dependent variable is TFPG; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

Table 7.27 Estimation Results of Model 4

Variable	All Sample	High Income	Upper Middle-Income	Lower Middle-Income
const	0.270988 (0.272182)	0.132316 (0.257054)	−0.396709 (0.327293)	1.12144*** (0.331185)
l_SM	0.0253368 (0.0178444)	−0.00753768 (0.0174915)	0.0669919*** (0.0205305)	0.0381301 (0.0293065)
l_SF	0.000271606 (0.00563646)	−0.00432681 (0.00595579)	0.00934269 (0.00669467)	−0.000513615 (0.00538157)
l_SP	0.0446395*** (0.0168481)	0.0409778** (0.0185735)	−0.0162741 (0.0175796)	−0.0704641** (0.0287343)
l_HC	0.0368216 (0.0801787)	−0.204898** (0.0960776)	−0.271574*** (0.0953601)	0.0169046 (0.0742975)
SPGAP	−0.00771071*** (0.00146463)	−0.0118846*** (0.00250680)	−0.00669956*** (0.00210261)	0.000841975 (0.00203909)

Notes: The dependent variable is TFPG; *, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%; Standard errors are reported in parenthesis below the coefficients.

Overall, the estimation results show that international technology diffusion has a crucial role in the TFP convergence process for developing countries. However, closing the productivity gap with developed countries is a heterogeneous process, and it varies across developing countries. In the analysis, this heterogeneity depends on the volume of international technology spillovers and the channels of the spillovers process.

CHAPTER VIII

CONCLUSION

Technological progress is the primary source of economic growth, and developed countries occupy a leading position in the realm of new technologies due to their established history of innovation and technological advancement; however, developing countries are deficient in the capacity to produce innovative technological expertise. At the point of closing this productivity gap between developing and developed countries, international technology diffusion emerges as a solution for less developed countries.

Hence, in light of the significance of international technology spillovers for the economic growth of developing countries, this thesis aims to examine the comparative impacts of various channels of technology diffusion on productivity while specifically investigating the disparities in the ability of developing countries to assimilate foreign technology. Furthermore, this study also analyses the impact of international technology diffusion on productivity convergence.

To achieve these aims, two different econometric models were constructed and estimated for 46 developing countries, and G7 countries were considered the only source of innovative activity in the world. The estimation period covers between 2000 and 2019. Since short-term panel data was used, the preferred estimation approach was predominantly random effects (RE), with fixed effects (FE) included where needed. To compare developing countries, these countries are classified as high-income, upper middle-income, and lower middle-income countries.

The first model, the TFP model, intended to demonstrate how TFP in developing countries is affected by international technology diffusion by focusing on the relative effectiveness of different diffusion channels and some country-specific factors. In this case, international technology diffusion channels are capital goods import (indirect channel), inward FDI flows (indirect channel), and patent applications (direct channel).

In the baseline model of the first model, TFP is the dependent variable, and it depends on the capital goods import weighted foreign R&D stocks, inward FDI flows weighted foreign R&D stocks, patent-weighted foreign R&D stocks, and human capital.

The estimation results of this baseline model show that the patent channel is the most powerful diffusion channel in all developing country groups; however, it affects TFP positively only in high-income countries. Inward FDI flows also contribute to foreign knowledge spillovers in high-income and upper middle-income countries, but their impact on domestic productivity is negative and weaker compared to the patent channel. Furthermore, the import of capital goods is ineffective for international technology diffusion in the baseline model. Capital goods import channel is only effective in lower middle-income countries, and it positively affects TFP.

As mentioned before, various country-specific factors influence the capacity of developing countries to assimilate foreign technology, and human capital is one of them. To evaluate the impact of human capital on the diffusion process, interaction terms between human capital and the diffusion channels were systematically incorporated into the model.

According to these models' results, human capital's role in international technology diffusion varies depending on the country classification and diffusion channels. Human capital is crucial for the absorption of import-embodied foreign knowledge and indirectly affects TFP. However, it does not significantly impact domestic productivity for high, upper-middle, and lower middle-income country groups. Furthermore, the interaction terms between human capital with FDI and patent channels have also a positive impact on TFP across the entire sample; however, only in high-income countries can differentiate themselves from upper middle and lower middle-income ones by human capital's indirect influence on TFP through FDI and patent-related knowledge spillovers.

The degree to which a country is open to trade, FDI, and patent application is another heterogeneous factor in international knowledge spillovers. For estimation, the baseline model was extended to include the interaction terms between openness factors and diffusion channel-weighted foreign R&D stocks. The findings indicate that developing nations with larger amounts of imports from the G7 and higher inflows of FDI and patent applications from the G7 are more likely to experience an increase in their TFP through the diffusion of foreign technology. When examining developing country groups more closely, however, it becomes clear that although trade openness is only an effective absorptive factor in upper middle-income developing countries, FDI and patent openness are only effective in high-income developing countries.

The institutions are another factor that assesses the extent to which countries benefit from foreign technology or the sources of heterogeneity in the spillover gains. One of these variables is EDB, which entered the model as a dummy variable that takes the value of 1 if the country is ranked in the top 60 in the WB ranking in 2019 and 0 otherwise. Additionally, this factor positively impacts the domestic productivity of developing countries through its interaction with all three diffusion channels for the entire sample, which means countries with more receptive institutional environments can benefit more from foreign knowledge spillovers. In specific developing country categories, EDB might be a distinctive feature in high-income and lower middle-income countries for capital goods imports and FDI inflows related to international technology diffusion; nevertheless, this factor makes a difference only in high-income countries for patent-embodied knowledge spillovers.

IPRI, the second institutional variable in this analysis, which represents the safeguarding of intellectual property rights, has a beneficial impact on attracting foreign knowledge through import, FDI, and patent channels for developing nations in the sample. However, only nations in the lower middle-income category with a higher ranking in IPRI are affected by international knowledge spillovers through all channels.

The final factor of variation among developing countries is the origin of their legal system. In developing countries with a legal system derived from British law, the diffusion of foreign knowledge through all channels favors total factor productivity (TFP). In addition, the genesis of the legal system in lower middle-income nations has an impact on aiding the international diffusion of technology, particularly through the patent channel.

The TFP convergence model, which is the second model, aimed to show the impact of international technology diffusion on the productivity catch-up between developing and developed countries. TFP growth is the dependent variable in this model, and it is affected by capital goods imports, inward FDI flows and patent application-related foreign R&D stocks, human capital, the TFP gap, and the interaction terms of diffusion channels with the TFP gap.

Overall, the estimation results of the convergence model suggest that worldwide technology diffusion plays a critical role in emerging countries' TFP convergence process. On the other hand, closing the productivity gap with developed countries is a multifaceted process that differs across developing countries. The analysis determines this heterogeneity by the volume of international technology spillovers and the channels through which the spillovers occur.

In general, the findings of this research demonstrated that the advantages that developing countries obtain from international technology diffusion differ based on the channel through which the technology spillovers and the characteristics of the country. Despite all these results, the significant influence of international technology diffusion on domestic productivity and the convergence process holds great significance for policy-makers. In addition to implementing policies that promote technological innovation, it is also crucial to highlight the significance of technological spillover. This enables developing nations to leverage current technology rather than creating new ones, aiding them in narrowing the disparity with rich nations in terms of production and income.

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APPENDICES

A. COUNTRY LIST

Table A.1 Countries in Figure 2.10 and 2.11

Developing	Developed
Albania	Australia
Algeria	Austria
Argentina	Belgium
Armenia	Bulgaria
Azerbaijan	Canada
Bangladesh	Croatia
Belarus	Czech Republic
Brazil	Denmark
Chile	Estonia
Colombia	Finland
Costa Rica	France
Ecuador	Germany
Egypt	Greece
Georgia	Hungary
Guatemala	Iceland
Honduras	Ireland
India	Italy
Indonesia	Japan
Iran	Latvia
Israel	Lithuania
Jamaica	Luxembourg
Kazakhstan	Malta
Kyrgyzstan	Netherlands
Madagascar	New Zealand
Malaysia	Norway
Mexico	Poland
Mongolia	Portugal
Morocco	Romania
Pakistan	Slovakia
Panama	Slovenia
Peru	Spain
Philippines	Sweden
Republic of Korea	Switzerland
Republic of Moldova	United Kingdom

Table A.1 (continued)

Russian Federation	United States of America
Saudi Arabia	
Singapore	
South Africa	
Sri Lanka	
Thailand	
Tunisia	
Turkey	
Turkmenistan	
Ukraine	
Uzbekistan	
Venezuela	
Vietnam	
Yemen	
Zambia	

B. SUMMARY STATISTICS-1

Table B.1 List of Developing Countries Covered in the Data Set

Country Name	Country Order (i)
Argentina	1
Bahrain	2
Brazil	3
Bulgaria	4
Chile	5
Colombia	6
Costa Rica	7
Dominican Republic	8
Ecuador	9
Egypt	10
Guatemala	11
Honduras	12
Hong Kong	13
Hungary	14
India	15
Indonesia	16
Iran	17
Israel	18
Jamaica	19
Jordan	20
Kazakhstan	21
Kenya	22
Malaysia	23
Mexico	24
Morocco	25
Nicaragua	26
Panama	27
Paraguay	28
Peru	29
Philippines	30
Poland	31
Qatar	32
Republic of Korea	33
Romania	34
Russian Federation	35
Saudi Arabia	36

Table B.1 (continued)

Serbia	37
Singapore	38
South Africa	39
Thailand	40
Trinidad and Tobago	41
Tunisia	42
Turkey	43
Ukraine	44
Uruguay	45
Venezuela	46

Table B.2 List of Developing Countries Covered in the Data Set

Country	**Country Order (j)**
Canada	1
France	2
Germany	3
Italy	4
Japan	5
United Kingdom	6
United States	7

Table B.3 Summary Statistics for Developing Countries (1)

Country	**TFP (Av.)**	**M_{it} (Av.)**	**S^{M}_{it} (Av.)**	**F_{it} (Av.)**
Argentina	0.3	1,548	1,010,696	475
Bahrain	3	627	700,909	106
Brazil	0.5	8,104	928,405	6,750
Bulgaria	0.6	1,254	377,745	427
Chile	0	3,431	1,005,751	2,694
Colombia	0	2,239	1,100,105	549
Costa Rica	0	657	1,373,957	141
Dominican Republic	0	645	1,381,628	164
Ecuador	1	924	1,152,390	24
Egypt	0.2	1,605	634,116	843
Guatemala	0.1	589	1,248,159	56

Table B.3 (continued)

Honduras	0.1	279	1,297,980	50
Hong Kong	0.1	13,808	772,084	8,323
Hungary	0	4,632	416,175	1,440
India	0	9,307	692,436	6,153
Indonesia	0	4,429	607,445	2,882
Iran	0	1,165	321,440	-4
Israel	0.3	4,277	892,874	1,647
Jamaica	0	179	1,277,869	-43
Jordan	1.5	834	621,181	101
Kazakhstan	0	926	535,571	482
Kenya	0	532	640,283	139
Malaysia	0.3	5,415	737,359	2,384
Mexico	0.1	20,628	1,415,172	6,975
Morocco	0.1	1,692	398,472	485
Nicaragua	0	121	1,292,403	32
Panama	1.1	9,220	665,168	509
Paraguay	0	292	1,390,701	-2
Peru	0.3	1,618	1,122,361	668
Philippines	0	3,674	699,601	1,022
Poland	0.3	10,844	388,118	4,106
Qatar	0.4	2,971	567,488	583
Republic of Korea	0	16,205	4,977,472	5,507
Romania	0.3	3,882	98,279	1,201
Russian Federation	0	13,095	838,600	3,502
Saudi Arabia	0.4	6,463	8,098,316	1,550
Serbia	0	881	21,666	197
Singapore	0.7	10,489	2,193,206	12,218
South Africa	0.1	6,253	176,647	2,552
Thailand	0	8,659	686,920	4,609
Trinidad and Tobago	0.2	508	1,310,805	396
Tunisia	0.7	876	326,723	187
Turkey	0.6	6,561	449,085	1,610
Ukraine	0.1	983	502,058	180
Uruguay	0	342	1,012,340	112
Venezuela	0.6	172	1,261,349	-80

Note: All values are the average of 2000-2019 and M_{it}, S^M_{it}, F_{it}, S^F_{it} and S^P_{it} variables are in millions.

Table B.4 Summary Statistics for Developing Countries (2)

Country	S^{F}_{it} (Av.)	Pi_{t} (Av.)	S^{P}_{it} (Av.)	H_{it} (Av.)
Argentina	965,006	961.3	674,539	9.57
Bahrain	1,918,641	60.75	639,726	8.2
Brazil	627,097	13835	1,092,008	7.69
Bulgaria	-892,224	108.3	672,704	10.62
Chile	29,869	1553.8	1,161,081	10.19
Colombia	928,648	724.35	921,181	8.76
Costa Rica	685,127	339.35	1,244,565	8.54
Dominican Republic	360,969	159.8	1,174,350	7.99
Ecuador	918,361	104.25	460,309	8.08
Egypt	675,681	667.1	889,757	7.22
Guatemala	446,169	172.4	1,149,236	5.09
Honduras	1,492,591	72.65	713,006	6.6
Hong Kong	834,260	8709.6	1,175,443	12.01
Hungary	128,487	166.75	831,101	11.86
India	847,976	16891	1,059,199	6.54
Indonesia	-153,382	1780.7	421,774	7.52
Iran	209,162	76.9	167,635	8.88
Israel	945,524	3821.1	1,341,899	11.91
Jamaica	1,821,939	21.05	347,619	10.01
Jordan	970,574	91.25	733,898	9.85
Kazakhstan	1,387,863	42.3	494,677	11.42
Kenya	-1,018,764	8.85	459,699	6.37
Malaysia	-4,971,732	3551	1,027,199	10.75
Mexico	1,328,507	10918	1,280,766	9.14
Morocco	283,222	506.5	697,562	5.31
Nicaragua	1,411,189	26.5	286,698	6.72
Panama	973,424	117.8	761,161	9.75
Paraguay	35,873	201.45	153,654	7.97
Peru	981,352	573.5	1,062,945	9.55
Philippines	1,079,517	818.95	558,066	8.65
Poland	443,586	589.1	921,426	11.52
Qatar	1,378,105	82.3	465,651	8.73
Republic of Korea	888,027	33004	944,037	12.78
Romania	556,461	75.85	1,033,763	11.03
Russian Federation	656,305	7410.4	936,942	11.73

Table B.4 (continued)

Saudi Arabia	1,363,179	516.25	732,099	8.41
Serbia	409,580	18.65	812,659	11
Singapore	1,438,267	5918.1	1,145,838	11.31
South Africa	363,486	2056.1	693,364	9.46
Thailand	2,332,602	3700.3	924,940	8.01
Trinidad and Tobago	1,021,024	19.05	97,473	10.64
Tunisia	357,008	34.55	186,158	7.84
Turkey	689,894	392.4	881,700	7.41
Ukraine	330,849	1212.2	953,322	10.91
Uruguay	-11,124,164	214.2	552,854	8.57
Venezuela	2,116,775	78.35	14,094	8.38

Table B.5 Summary Statistics for Developing Countries (3)

Country	**MOP (Av.)**	**FOP (Av.)**	**POP (Av.)**
Argentina	0.01	0.001	0.00002229
Bahrain	0.06	0.002	0.00004228
Brazil	0.02	0.003	0.00007084
Bulgaria	0.05	0.004	0.00001375
Chile	0.04	0.008	0.00009185
Colombia	0.02	0.001	0.00001571
Costa Rica	0.08	0.002	0.00007408
Dominican Republic	0.05	0.001	0.00001659
Ecuador	0.04	0.000	0.00000701
Egypt	0.01	0.001	0.00000802
Guatemala	0.05	0.001	0.00001199
Honduras	0.11	0.002	0.00000878
Hong Kong	0.22	0.021	0.00124781
Hungary	0.12	0.006	0.00001648
India	0.01	0.001	0.00001353
Indonesia	0.01	0.001	0.00000681
Iran	0.00	0.000	0.00000095
Israel	0.10	0.006	0.00053771
Jamaica	0.08	-0.002	0.00000767
Jordan	0.06	0.001	0.00001069
Kazakhstan	0.01	0.001	0.00000246

Table B.5 (continued)

Kenya	0.02	0.001	0.00000019
Malaysia	0.06	0.004	0.00012835
Mexico	0.07	0.004	0.00009682
Morocco	0.05	0.002	0.00001482
Nicaragua	0.03	0.001	0.00000458
Panama	0.25	0.010	0.00003150
Paraguay	0.03	0.000	0.00002878
Peru	0.03	0.002	0.00001955
Philippines	0.04	0.002	0.00000802
Poland	0.07	0.005	0.00001535
Qatar	0.05	0.005	0.00003113
Republic of Korea	0.07	0.003	0.00066492
Romania	0.05	0.003	0.00000358
Russian Federation	0.01	0.001	0.00005131
Saudi Arabia	0.03	0.001	0.00001727
Serbia	0.03	0.002	0.00000255
Singapore	0.23	0.037	0.00118809
South Africa	0.03	0.004	0.00003757
Thailand	0.05	0.005	0.00005518
Trinidad and Tobago	0.07	0.010	0.00001472
Tunisia	0.06	0.002	0.00000304
Turkey	0.02	0.001	0.00000583
Ukraine	0.01	0.000	0.00002647
Uruguay	0.03	0.002	0.00006371
Venezuela	0.08	-0.029	0.00000324

Table B.6 Institutional Statistics for Developing Countries

Country	EDB 2019 Global Rank	IPRI 2019 Global Rank	Origin of Legal System
Argentina	126	91	French
Bahrain	43	38	French
Brazil	124	78	French
Bulgaria	61	64	German
Chile	59	33	French
Colombia	67	74	French
Costa Rica	74	44	French

Table B.6 (continued)

Dominican Republic	115	87	French
Ecuador	129	100	French
Egypt	114	70	French
Guatemala	96	103	French
Honduras	133	104	French
Hong Kong	3	16	German
Hungary	52	52	German
India	63	58	English
Indonesia	73	67	French
Iran	127	113	French
Israel	35	25	English
Jamaica	71	57	English
Jordan	75	43	French
Kazakhstan	25	75	French
Kenya	56	86	English
Malaysia	12	29	English
Mexico	60	77	French
Morocco	53	55	French
Nicaragua	142	119	French
Panama	86	68	French
Paraguay	125	101	French
Peru	76	92	French
Philippines	95	83	French
Poland	40	53	German
Qatar	77	26	English
Republic of Korea	5	28	German
Romania	55	50	French
Russian Federation	28	85	French
Saudi Arabia	62	35	English
Serbia	44	80	French
Singapore	2	2	English
South Africa	84	48	English
Thailand	21	69	English
Trinidad and Tobago	105	62	English
Tunisia	78	76	French
Turkey	33	81	French
Ukraine	64	105	French

Table B.6 (continued)

Uruguay	101	34	French
Venezuela	188	129	French

Table B.7 TFP Growth Rates of Developing Countries (1)

Country	2000	2001	2002	2003	2004	2005	2006
Argentina	-0.02	-0.04	-0.7	0.13	0.04	0.05	-0.01
Bahrain	0.02	-0.01	-0.02	0	0.01	-0.02	-0.02
Brazil	-0.01	-0.23	-0.21	-0.06	0.06	0.2	0.12
Bulgaria	-0.11	-0.03	0.05	0.19	0.09	0	0
Chile	-0.05	-0.15	-0.09	0	0.16	0.11	0.06
Colombia	-0.17	-0.09	-0.1	-0.12	0.11	0.13	-0.01
Costa Rica	-0.08	-0.06	-0.1	-0.1	-0.1	-0.09	-0.04
Dominican Republic	0	-0.03	-0.08	-0.41	-0.29	0.45	-0.04
Ecuador	-0.03	0	0	-0.01	0.03	0	0.01
Egypt	-0.03	-0.14	-0.13	-0.24	-0.06	0.06	0.01
Guatemala	-0.06	-0.02	0.01	-0.02	0	0.04	0.01
Honduras	-0.01	-0.03	-0.05	-0.04	-0.02	-0.02	0.02
Hong Kong	0.02	-0.04	-0.01	0.01	0.04	0.03	0.04
Hungary	-0.14	0.01	0.15	0.17	0.14	0.05	-0.03
India	-0.06	-0.05	-0.04	0.07	0.05	0.05	0
Indonesia	-0.06	-0.18	0.12	0.1	-0.03	-0.06	0.08
Iran	-0.28	-0.11	-0.09	-0.14	-0.08	-0.06	-0.01
Israel	0.05	-0.04	-0.13	0.04	0.05	0.01	0.03
Jamaica	-0.09	-0.07	-0.11	-0.14	-0.05	-0.02	-0.07
Jordan	0.01	0.03	0.04	0.02	0.04	0.01	0.01
Kazakhstan	-0.09	0.04	0.04	0.08	0.16	0.08	0.12
Kenya	-0.11	-0.02	-0.03	0.04	-0.03	0.06	0.05
Malaysia	0.04	-0.03	0.01	0.01	0.03	0.01	0.04
Mexico	0.03	-0.02	-0.07	-0.11	-0.03	0.04	0.02
Morocco	-0.1	-0.01	0.02	0.16	0.08	-0.01	0.05
Nicaragua	-0.08	-0.05	-0.08	-0.06	-0.04	-0.04	-0.04
Panama	0	-0.02	-0.01	0.01	0.03	0.02	0.04
Paraguay	-0.15	-0.15	-0.19	-0.1	0.06	-0.05	0.13
Peru	-0.05	-0.02	0.02	0.02	0.03	0.06	0.04
Philippines	-0.11	-0.12	-0.01	-0.04	-0.01	0.03	0.1
Poland	-0.05	0.07	0.03	0.07	0.09	0.13	0.06

Table B.7 (continued)

Qatar	0.01	-0.06	-0.02	-0.11	0.04	-0.08	-0.01
Republic of Korea	0.07	-0.12	0.06	0.06	0.06	0.14	0.09
Romania	-0.28	-0.22	-0.04	0.03	0.09	0.16	0.08
Russian Federation	-0.05	0.01	-0.03	0.09	0.13	0.06	0.1
Saudi Arabia	0.02	-0.04	-0.06	0.05	0.01	-0.02	-0.06
Serbia	-0.54	-0.3	0.13	0.18	0.05	-0.05	0.05
Singapore	-0.01	-0.08	0.01	0.06	0.1	0.04	0.06
South Africa	-0.1	-0.17	-0.19	0.44	0.18	0.03	-0.08
Thailand	-0.05	-0.07	0.06	0.07	0.05	0.01	0.08
Trinidad and Tobago	0.05	0.03	0.07	0.1	0.04	0	0.1
Tunisia	-0.13	-0.05	0	0.12	0.07	-0.04	-0.01
Turkey	-0.31	-0.53	-0.15	0.03	0.1	0.07	-0.07
Ukraine	-0.2	0.12	0.07	0.1	0.12	0.05	0.08
Uruguay	-0.08	-0.12	-0.4	-0.23	0	0.24	0.02
Venezuela	-0.1	-0.07	-0.44	-0.33	-0.04	-0.04	0.01

Table B.8 TFP Growth Rates of Developing Countries (2)

Country	2007	2008	2009	2010	2011	2012	2013
Argentina	0.02	-0.02	-0.21	0.01	-0.04	-0.12	-0.17
Bahrain	-0.02	-0.04	-0.04	0	-0.01	-0.02	-0.01
Brazil	0.15	0.07	-0.11	0.16	0.03	-0.16	-0.1
Bulgaria	0.07	0.03	-0.09	-0.04	0.07	-0.09	0.02
Chile	0.01	-0.02	-0.11	0.11	0.06	-0.01	-0.03
Colombia	0.13	0.04	-0.1	0.14	0.05	0.03	-0.03
Costa Rica	0.01	-0.02	-0.1	0.13	0.03	0.04	0.01
Dominican Republic	0.02	-0.07	-0.06	0	-0.04	-0.04	-0.05
Ecuador	-0.01	0.01	-0.02	-0.01	0.04	0.03	0.01
Egypt	0	0.02	-0.03	-0.02	-0.08	-0.04	-0.13
Guatemala	0	0.01	-0.09	0.01	0.04	-0.05	0.04
Honduras	0.01	-0.02	-0.05	0	0.01	-0.02	-0.08
Hong Kong	0.02	0.01	-0.03	0.03	0.01	-0.01	0
Hungary	0.14	0.07	-0.2	-0.02	0.05	-0.13	0.01
India	0.11	-0.07	-0.08	0.09	-0.03	-0.12	-0.08
Indonesia	0	-0.05	-0.07	0.16	0.07	-0.06	-0.09

Table B.8 (continued)

Iran	0.03	-0.05	-0.07	-0.02	-0.05	-0.21	-0.35
Israel	0.09	0.13	-0.11	0.07	0.06	-0.08	0.08
Jamaica	-0.06	-0.06	-0.18	0.01	0.03	-0.04	-0.12
Jordan	0	0.02	-0.01	-0.03	-0.02	-0.02	-0.01
Kazakhstan	0.07	0.01	-0.19	0.03	0.05	0	0.01
Kenya	0.09	-0.07	-0.1	0.03	-0.1	0.04	-0.03
Malaysia	0.08	0.04	-0.1	0.1	0.06	-0.01	-0.03
Mexico	-0.01	-0.05	-0.22	0.06	0.03	-0.05	0.02
Morocco	0.05	0.07	0.01	-0.05	0.06	-0.07	0.03
Nicaragua	-0.04	-0.04	-0.08	-0.04	-0.04	-0.04	-0.04
Panama	0.04	-0.01	-0.04	-0.01	0.02	0	-0.03
Paraguay	0.13	0.19	-0.14	0.13	0.13	-0.11	0.08
Peru	0.08	0.1	-0.06	0.09	0.02	0.04	-0.02
Philippines	0.14	0.05	-0.09	0.09	0.04	0.06	0.03
Poland	0.13	0.14	-0.22	0.07	0.04	-0.1	0.02
Qatar	-0.09	-0.05	-0.05	0.02	0	-0.06	-0.07
Republic of Korea	0.05	-0.14	-0.14	0.14	0.05	-0.02	0.03
Romania	0.16	0	-0.23	-0.07	0.05	-0.11	0.06
Russian Federation	0.11	0.06	-0.27	0.07	0.05	-0.03	-0.02
Saudi Arabia	-0.07	-0.03	-0.09	-0.04	-0.01	-0.02	-0.04
Serbia	0.18	0.04	-0.16	-0.09	0.11	-0.18	0.03
Singapore	0.06	0.01	-0.07	0.14	0.09	-0.02	-0.02
South Africa	-0.03	-0.16	-0.05	0.18	-0.01	-0.11	-0.16
Thailand	0.11	0.01	-0.07	0.13	0.02	0.03	0.03
Trinidad and Tobago	0.03	0.02	-0.08	0	-0.05	-0.03	-0.05
Tunisia	0.07	0.05	-0.08	-0.06	-0.01	-0.1	-0.05
Turkey	0.09	-0.04	-0.22	0.05	-0.07	-0.08	-0.03
Ukraine	0.07	-0.03	-0.4	-0.01	0.05	0	0
Uruguay	0.05	0.14	-0.05	0.18	0.05	-0.04	0.01
Venezuela	0.03	0	-0.06	-0.2	-0.39	0.02	-0.31

Table B.9 TFP Growth Rates of Developing Countries (3)

Country	2014	2015	2016	2017	2018	2019
Argentina	-0.35	-0.13	-0.38	-0.11	-0.43	-0.44
Bahrain	-0.01	-0.02	-0.02	0	-0.03	-0.02

Table B.9 (continued)

Brazil	-0.11	-0.33	-0.08	0.09	-0.14	-0.09
Bulgaria	-0.01	-0.16	0.02	0.02	0.06	-0.05
Chile	-0.14	-0.14	-0.04	0.03	0.03	-0.1
Colombia	-0.06	-0.28	-0.11	0.03	0	-0.09
Costa Rica	-0.07	0	-0.03	-0.03	0	-0.01
Dominican Republic	-0.03	-0.01	-0.01	-0.04	-0.03	-0.04
Ecuador	0.01	-0.02	-0.01	-0.01	-0.02	-0.01
Egypt	-0.03	-0.07	-0.23	-0.43	0	0.06
Guatemala	0.02	0.02	0	0.03	-0.03	-0.02
Honduras	-0.02	-0.06	-0.03	-0.03	-0.05	-0.01
Hong Kong	0.02	0	0.01	0.02	0	-0.02
Hungary	-0.04	-0.16	-0.02	0.05	0.04	-0.06
India	-0.01	-0.01	-0.01	0.06	-0.03	-0.03
Indonesia	-0.11	-0.1	0.02	0	-0.05	0.01
Iran	-0.27	-0.14	0.04	-0.06	-0.24	-0.1
Israel	0.02	-0.09	0.01	0.06	0	0.01
Jamaica	-0.1	-0.05	-0.07	-0.03	0	-0.04
Jordan	-0.02	-0.02	-0.01	-0.02	-0.02	-0.01
Kazakhstan	-0.14	-0.21	-0.36	0.07	-0.05	-0.09
Kenya	-0.04	-0.11	-0.02	-0.01	0.04	0.01
Malaysia	-0.03	-0.16	-0.06	-0.03	0.07	-0.02
Mexico	-0.03	-0.16	-0.15	-0.02	-0.02	-0.02
Morocco	0.01	-0.12	0	0.04	0.03	-0.02
Nicaragua	-0.05	-0.05	-0.05	-0.04	-0.1	-0.09
Panama	-0.04	-0.03	-0.03	-0.02	-0.04	-0.03
Paraguay	-0.01	-0.15	-0.07	0.02	-0.04	-0.11
Peru	-0.07	-0.12	-0.05	0.03	0	-0.03
Philippines	-0.02	-0.01	-0.05	-0.04	-0.04	0.02
Poland	0	-0.16	-0.04	0.07	0.08	-0.04
Qatar	-0.06	-0.06	-0.08	-0.06	-0.06	-0.07
Republic of Korea	0.04	-0.07	-0.02	0.04	0.04	-0.06
Romania	0.01	-0.14	0.01	0.05	0.05	-0.06
Russian Federation	-0.17	-0.39	-0.09	0.16	-0.05	-0.02
Saudi Arabia	-0.03	-0.03	-0.04	-0.06	-0.02	-0.03
Serbia	-0.12	-0.19	-0.03	0.02	0.09	-0.04
Singapore	-0.03	-0.09	-0.02	0	0.01	-0.05
South Africa	-0.12	-0.18	-0.15	0.09	-0.01	-0.1

Table B.9 (continued)

Thailand	-0.05	-0.02	-0.02	0.1	0.06	0.05
Trinidad and Tobago	-0.09	-0.04	-0.15	-0.09	-0.02	-0.02
Tunisia	-0.04	-0.15	-0.1	-0.11	-0.09	-0.11
Turkey	-0.14	-0.2	-0.12	-0.16	-0.26	-0.16
Ukraine	-0.33	-0.48	-0.12	-0.01	0	0.08
Uruguay	-0.12	-0.16	-0.09	0.07	-0.06	-0.14
Venezuela	-0.32	-0.56	-0.8	-0.89	-1	-1

Table B.10 TFP Gap Between Developing Countries and G7 Countries (1)

Country	2000	2001	2002	2003	2004	2005	2006
Argentina	0.15	0.14	-0.57	-0.65	-0.73	-0.72	-0.75
Bahrain	2.64	2.62	2.52	2.4	2.33	2.26	2.19
Brazil	-0.22	-0.34	-0.47	-0.61	-0.68	-0.61	-0.58
Bulgaria	-0.34	-0.33	-0.33	-0.34	-0.38	-0.39	-0.41
Chile	-0.85	-0.83	-0.86	-0.97	-1.06	-1.07	-1.09
Colombia	-0.85	-0.83	-0.86	-0.97	-1.07	-1.08	-1.1
Costa Rica	-0.85	-0.83	-0.86	-0.97	-1.06	-1.07	-1.09
Dominican Republic	-0.8	-0.78	-0.81	-0.95	-1.04	-1.05	-1.07
Ecuador	0.09	0.11	0.09	-0.04	-0.1	-0.11	-0.12
Egypt	-0.52	-0.54	-0.61	-0.78	-0.89	-0.89	-0.91
Guatemala	-0.72	-0.7	-0.73	-0.85	-0.94	-0.94	-0.96
Honduras	-0.79	-0.77	-0.8	-0.92	-1.01	-1.02	-1.04
Hong Kong	-0.74	-0.73	-0.76	-0.87	-0.96	-0.96	-0.98
Hungary	-0.85	-0.83	-0.86	-0.97	-1.06	-1.07	-1.09
India	-0.84	-0.81	-0.84	-0.96	-1.05	-1.06	-1.08
Indonesia	-0.85	-0.83	-0.86	-0.97	-1.07	-1.08	-1.1
Iran	-0.85	-0.83	-0.86	-0.97	-1.07	-1.08	-1.1
Israel	-0.61	-0.6	-0.66	-0.76	-0.85	-0.85	-0.87
Jamaica	-0.83	-0.81	-0.84	-0.96	-1.05	-1.06	-1.08
Jordan	0.57	0.64	0.67	0.58	0.55	0.56	0.56
Kazakhstan	-0.85	-0.83	-0.86	-0.97	-1.06	-1.07	-1.09
Kenya	-0.84	-0.82	-0.85	-0.96	-1.05	-1.06	-1.08
Malaysia	-0.6	-0.59	-0.61	-0.72	-0.81	-0.81	-0.82
Mexico	-0.74	-0.71	-0.75	-0.88	-0.97	-0.98	-1
Morocco	-0.78	-0.76	-0.78	-0.88	-0.97	-0.98	-1

Table B.10 (continued)

Nicaragua	-0.78	-0.76	-0.79	-0.91	-1	-1.02	-1.04
Panama	0.27	0.27	0.22	0.12	0.06	0.07	0.1
Paraguay	-0.85	-0.83	-0.86	-0.97	-1.07	-1.08	-1.1
Peru	-0.6	-0.58	-0.6	-0.71	-0.79	-0.78	-0.79
Philippines	-0.84	-0.82	-0.84	-0.96	-1.05	-1.06	-1.08
Poland	-0.66	-0.62	-0.65	-0.75	-0.82	-0.79	-0.8
Qatar	-0.22	-0.24	-0.28	-0.46	-0.53	-0.58	-0.61
Republic of Korea	-0.85	-0.83	-0.86	-0.97	-1.06	-1.08	-1.1
Romania	-0.54	-0.58	-0.62	-0.73	-0.8	-0.77	-0.77
Russian Federation	-0.83	-0.81	-0.84	-0.95	-1.04	-1.04	-1.06
Saudi Arabia	-0.36	-0.36	-0.42	-0.51	-0.6	-0.62	-0.67
Serbia	-0.84	-0.82	-0.85	-0.96	-1.05	-1.06	-1.08
Singapore	-0.26	-0.28	-0.31	-0.39	-0.43	-0.41	-0.39
South Africa	-0.7	-0.7	-0.76	-0.83	-0.89	-0.9	-0.93
Thailand	-0.84	-0.81	-0.84	-0.95	-1.04	-1.05	-1.07
Trinidad and Tobago	-0.67	-0.64	-0.66	-0.75	-0.83	-0.84	-0.84
Tunisia	-0.15	-0.15	-0.19	-0.22	-0.26	-0.3	-0.33
Turkey	0.82	-0.04	-0.19	-0.29	-0.31	-0.26	-0.34
Ukraine	-0.74	-0.7	-0.72	-0.82	-0.9	-0.9	-0.91
Uruguay	-0.79	-0.77	-0.82	-0.95	-1.04	-1.04	-1.06
Venezuela	1.46	1.33	0.35	-0.17	-0.29	-0.33	-0.34

Notes: TFP gap is the difference of the TFP of each non-frontier developing country in the sample from the average TFP of G7 countries.

Table B.11 TFP Gap Between Developing Countries and G7 Countries (2)

Country	2007	2008	2009	2010	2011	2012	2013
Argentina	-0.82	-0.83	-0.79	-0.78	-0.84	-0.81	-0.87
Bahrain	2.04	1.89	1.89	1.88	1.8	1.81	1.77
Brazil	-0.58	-0.54	-0.49	-0.39	-0.42	-0.47	-0.54
Bulgaria	-0.44	-0.42	-0.37	-0.39	-0.39	-0.4	-0.4
Chile	-1.17	-1.18	-1.06	-1.06	-1.1	-1.05	-1.06
Colombia	-1.18	-1.18	-1.06	-1.06	-1.1	-1.05	-1.06
Costa Rica	-1.17	-1.18	-1.06	-1.06	-1.1	-1.05	-1.06
Dominican Republic	-1.15	-1.15	-1.04	-1.03	-1.08	-1.02	-1.04

Table B.11 (continued)

Ecuador	-0.21	-0.2	-0.1	-0.11	-0.12	-0.03	-0.04
Egypt	-0.98	-0.98	-0.87	-0.87	-0.93	-0.88	-0.92
Guatemala	-1.04	-1.04	-0.94	-0.93	-0.98	-0.93	-0.93
Honduras	-1.12	-1.12	-1.01	-1	-1.05	-1	-1.01
Hong Kong	-1.05	-1.06	-0.94	-0.94	-0.98	-0.93	-0.94
Hungary	-1.17	-1.17	-1.06	-1.05	-1.1	-1.04	-1.06
India	-1.16	-1.16	-1.04	-1.04	-1.09	-1.03	-1.05
Indonesia	-1.18	-1.18	-1.06	-1.06	-1.11	-1.05	-1.06
Iran	-1.18	-1.18	-1.06	-1.06	-1.11	-1.05	-1.06
Israel	-0.93	-0.9	-0.81	-0.79	-0.82	-0.79	-0.78
Jamaica	-1.16	-1.16	-1.05	-1.05	-1.09	-1.04	-1.05
Jordan	0.47	0.49	0.59	0.55	0.47	0.5	0.47
Kazakhstan	-1.17	-1.17	-1.06	-1.05	-1.1	-1.04	-1.05
Kenya	-1.16	-1.16	-1.05	-1.04	-1.09	-1.04	-1.05
Malaysia	-0.88	-0.87	-0.78	-0.75	-0.78	-0.73	-0.75
Mexico	-1.08	-1.08	-0.99	-0.98	-1.02	-0.97	-0.98
Morocco	-1.07	-1.06	-0.95	-0.95	-0.99	-0.94	-0.95
Nicaragua	-1.12	-1.13	-1.01	-1.01	-1.06	-1.01	-1.02
Panama	0.07	0.05	0.12	0.11	0.08	0.13	0.08
Paraguay	-1.18	-1.18	-1.06	-1.06	-1.11	-1.05	-1.06
Peru	-0.85	-0.82	-0.72	-0.69	-0.73	-0.66	-0.68
Philippines	-1.16	-1.16	-1.04	-1.04	-1.08	-1.03	-1.04
Poland	-0.84	-0.79	-0.76	-0.74	-0.78	-0.75	-0.76
Qatar	-0.73	-0.76	-0.66	-0.65	-0.7	-0.66	-0.7
Republic of Korea	-1.17	-1.18	-1.06	-1.06	-1.1	-1.05	-1.06
Romania	-0.79	-0.8	-0.77	-0.78	-0.82	-0.79	-0.79
Russian Federation	-1.14	-1.14	-1.03	-1.03	-1.07	-1.02	-1.03
Saudi Arabia	-0.78	-0.79	-0.71	-0.72	-0.77	-0.72	-0.75
Serbia	-1.16	-1.16	-1.05	-1.04	-1.09	-1.04	-1.05
Singapore	-0.43	-0.42	-0.35	-0.25	-0.23	-0.19	-0.22
South Africa	-1.02	-1.04	-0.93	-0.91	-0.96	-0.92	-0.95
Thailand	-1.15	-1.15	-1.04	-1.03	-1.08	-1.02	-1.03
Trinidad and Tobago	-0.91	-0.91	-0.81	-0.81	-0.87	-0.82	-0.84
Tunisia	-0.36	-0.32	-0.27	-0.32	-0.37	-0.39	-0.43
Turkey	-0.35	-0.39	-0.44	-0.41	-0.5	-0.49	-0.52

Table B.11 (continued)

Ukraine	-0.97	-0.98	-0.94	-0.94	-0.98	-0.92	-0.94
Uruguay	-1.14	-1.14	-1.02	-1.01	-1.06	-1	-1.01
Venezuela	-0.4	-0.4	-0.33	-0.47	-0.75	-0.68	-0.81

Table B.12 TFP Gap Between Developing Countries and G7 Countries (3)

Country	2014	2015	2016	2017	2018	2019
Argentina	-0.94	-0.83	-0.84	-0.86	-0.92	-0.89
Bahrain	1.73	1.79	1.76	1.74	1.63	1.63
Brazil	-0.61	-0.63	-0.63	-0.61	-0.68	-0.67
Bulgaria	-0.41	-0.39	-0.34	-0.35	-0.34	-0.33
Chile	-1.07	-0.94	-0.91	-0.92	-0.95	-0.91
Colombia	-1.07	-0.94	-0.91	-0.92	-0.95	-0.91
Costa Rica	-1.07	-0.94	-0.91	-0.92	-0.95	-0.91
Dominican Republic	-1.05	-0.92	-0.89	-0.9	-0.93	-0.89
Ecuador	-0.04	0.07	0.09	0.08	0.03	0.06
Egypt	-0.93	-0.81	-0.81	-0.87	-0.9	-0.85
Guatemala	-0.94	-0.81	-0.78	-0.79	-0.82	-0.78
Honduras	-1.02	-0.9	-0.87	-0.88	-0.91	-0.87
Hong Kong	-0.94	-0.82	-0.79	-0.79	-0.82	-0.79
Hungary	-1.06	-0.94	-0.91	-0.92	-0.95	-0.91
India	-1.05	-0.93	-0.9	-0.91	-0.94	-0.9
Indonesia	-1.07	-0.94	-0.91	-0.92	-0.95	-0.91
Iran	-1.07	-0.94	-0.91	-0.92	-0.95	-0.91
Israel	-0.78	-0.68	-0.65	-0.64	-0.67	-0.63
Jamaica	-1.06	-0.93	-0.9	-0.91	-0.94	-0.9
Jordan	0.43	0.52	0.53	0.49	0.42	0.44
Kazakhstan	-1.06	-0.94	-0.91	-0.92	-0.95	-0.91
Kenya	-1.06	-0.93	-0.9	-0.91	-0.94	-0.9
Malaysia	-0.77	-0.69	-0.67	-0.69	-0.7	-0.67
Mexico	-0.99	-0.88	-0.86	-0.87	-0.9	-0.86
Morocco	-0.95	-0.84	-0.81	-0.82	-0.85	-0.81
Nicaragua	-1.03	-0.91	-0.88	-0.89	-0.92	-0.88
Panama	0.03	0.12	0.11	0.08	0	0.01
Paraguay	-1.07	-0.94	-0.91	-0.92	-0.95	-0.91
Peru	-0.71	-0.63	-0.61	-0.62	-0.65	-0.61
Philippines	-1.05	-0.92	-0.89	-0.9	-0.93	-0.89

Table B.12 (continued)

Poland	-0.76	-0.69	-0.67	-0.66	-0.66	-0.64
Qatar	-0.73	-0.62	-0.62	-0.65	-0.69	-0.67
Republic of Korea	-1.07	-0.94	-0.91	-0.92	-0.95	-0.91
Romania	-0.8	-0.71	-0.68	-0.68	-0.69	-0.67
Russian Federation	-1.04	-0.93	-0.9	-0.91	-0.94	-0.9
Saudi Arabia	-0.76	-0.65	-0.63	-0.66	-0.69	-0.66
Serbia	-1.06	-0.93	-0.9	-0.91	-0.94	-0.9
Singapore	-0.25	-0.2	-0.19	-0.2	-0.22	-0.22
South Africa	-0.97	-0.86	-0.84	-0.85	-0.88	-0.85
Thailand	-1.04	-0.92	-0.89	-0.89	-0.92	-0.88
Trinidad and Tobago	-0.87	-0.75	-0.75	-0.77	-0.81	-0.77
Tunisia	-0.46	-0.43	-0.45	-0.51	-0.57	-0.58
Turkey	-0.6	-0.57	-0.58	-0.65	-0.75	-0.74
Ukraine	-0.99	-0.9	-0.87	-0.88	-0.91	-0.87
Uruguay	-1.03	-0.91	-0.88	-0.89	-0.92	-0.88
Venezuela	-0.89	-0.87	-0.9	-0.92	-0.95	-0.91

C. SUMMARY STATISTICS-2

Table C.1 Correlation Matrix of TFP Model (1)

No	Variable	1	2	3	4	5	6	7
1	**TFP**	1						
2	***$logS^M$***	-0.0237	1					
3	***$logS^F$***	0.0159	0.4725	1				
4	***$logS^P$***	0.0335	0.4446	0.5531	1			
5	***logH***	-0.0051	0.0077	0.1057	0.0777	1		
6	***$logS^M$ * logH***	-0.0115	0.363	0.2499	0.2231	0.934	1	
7	***$logS^F$ * logH***	0.001	0.1905	0.4346	0.2656	0.9408	0.9388	1
8	***$logS^P$ * logH***	-0.0024	0.0426	0.1444	0.257	0.9833	0.9468	0.9621
9	***logMOP***	0.1873	0.2336	0.237	0.2126	0.2698	0.3332	0.3275
10	***logFOP***	0.047	0.1419	0.2684	0.2102	0.3276	0.3528	0.4069
11	***logPOP***	0.0509	0.4369	0.2114	0.0958	0.2548	0.4037	0.3159
12	***$logS^M$ * logMOP***	0.1936	0.1061	0.1838	0.1573	0.2783	0.2959	0.3131
13	***$logS^F$ * logFOP***	0.0581	0.0768	0.097	0.1049	0.3444	0.3469	0.3439
14	***$logS^P$ * logPOP***	0.0491	0.3915	0.153	-0.016	0.2499	0.3841	0.2912
15	***$logS^M$ * DEDB***	0.0358	-0.1272	0.0066	-0.0541	0.3482	0.2848	0.3233
16	***$logS^F$ * DEDB***	0.054	-0.129	0.018	-0.0439	0.3368	0.2762	0.3294
17	***$logS^P$ * DEDB***	-0.042	-0.1182	0.027	-0.0504	0.4345	0.3691	0.4096
18	***$logS^M$ * DIPRI***	0.1504	0.1108	0.0239	0.0178	0.28	0.3053	0.2523
19	***$logS^F$ * DIPRI***	0.166	0.0847	0.0418	0.0237	0.2571	0.275	0.2599
20	***$logS^P$ * DIPRI***	0.0714	0.1047	0.0505	0.0211	0.3426	0.3626	0.321
21	***$logS^M$ * DLEGAL***	-0.0837	0.1658	0.0433	0.0521	0.0471	0.1052	0.0646
22	***$logS^F$ * DLEGAL***	-0.0768	0.1463	0.0607	0.0604	0.0394	0.0915	0.0727
23	***$logS^P$ * DLEGAL***	-0.068	0.1588	0.1174	0.055	0.0664	0.12	0.0974

Table C.2 Correlation Matrix of TFP Model (2)

No	Variable	8	9	10	11	12	13	14
8	***$logS^P$ * logH***	1						
9	***logMOP***	0.3282	1					
10	***logFOP***	0.3368	0.5961	1				
11	***logPOP***	0.2673	0.3622	0.3728	1			
12	***$logS^M$ * logMOP***	0.3298	0.9911	0.5888	0.3228	1		
13	***$logS^F$ * logFOP***	0.3418	0.6113	0.9839	0.3704	0.6118	1	
14	***$logS^P$ * logPOP***	0.2423	0.3404	0.351	0.9935	0.3069	0.36	1

Table C.2 (continued)

15	***$logS^M$ * DEDB***	0.3953	0.2414	0.3123	0.23	0.2665	0.334	0.2358
16	***$logS^F$ * DEDB***	0.3836	0.2485	0.3494	0.2143	0.271	0.3303	0.2192
17	***$logS^P$ * DEDB***	0.3939	0.2909	0.3455	0.1981	0.3134	0.3654	0.2032
18	***$logS^M$ * DIPRI***	0.2932	0.3745	0.3292	0.3799	0.3692	0.3594	0.3797
19	***$logS^F$ * DIPRI***	0.2742	0.3621	0.3795	0.3756	0.3601	0.3621	0.3754
20	***$logS^P$ * DIPRI***	0.293	0.375	0.3551	0.3619	0.3715	0.3756	0.3613
21	***$logS^M$ * DLEGAL***	0.0044	0.1201	0.2049	0.2559	0.1033	0.2292	0.252
22	***$logS^F$ * DLEGAL***	-0.0094	0.1128	0.2492	0.2617	0.0985	0.2325	0.2571
23	***$logS^P$ * DLEGAL***	0.0045	0.1105	0.1989	0.2546	0.0946	0.2013	0.2504

Table C.3 Correlation Matrix of TFP Model (3)

No	Variable	15	16	17	18	19	20	21	22	23
15	***$logS^M$ * DEDB***	1								
16	***$logS^F$ * DEDB***	0.9987	1							
17	***$logS^P$ * DEDB***	0.9987	0.9994	1						
18	***$logS^M$ * DIPRI***	0.311	0.3049	0.3405	1					
19	***$logS^F$ * DIPRI***	0.3165	0.3371	0.3448	0.9984	1				
20	***$logS^P$ * DIPRI***	0.4006	0.3937	0.4507	0.9989	0.9994	1			
21	***$logS^M$ * DLEGAL***	0.0671	0.0558	0.0605	0.3564	0.3504	0.3146	1		
22	***$logS^F$ * DLEGAL***	0.0627	0.0801	0.0613	0.3448	0.3679	0.3024	0.9986	1	
23	***$logS^P$ * DLEGAL***	0.1748	0.1691	0.1994	0.3718	0.367	0.4064	0.9994	0.9995	1

Table C.4 Summary Statistics of Dependent and Independent Variables for Sample Countries

Variable	Mean	Median	Stand. Dev.	Min	Max
TFP	0.310	0.109	0.540	7.43e-009	3.50
$logS^M$	27.2	27.3	1.04	21.0	30.4
$logS^F$	27.2	27.4	1.09	22.5	31.3
$logS^P$	27.6	27.8	0.540	25.6	28.4
logH	2.19	2.21	0.228	1.41	2.61
$logS^M$ * logH	59.6	60.0	6.66	35.8	76.8
$logS^F$ * logH	59.5	60.2	6.91	36.1	73.5
$logS^P$ * logH	61.6	63.0	6.64	38.8	73.0
logMOP	-3.42	-3.17	1.38	-10.0	10.2
logFOP	-6.31	-6.15	1.73	-15.8	8.78
logPOP	-10.4	-10.4	1.88	-15.8	-6.47
$logS^M$ * logMOP	-93.0	-85.2	37.4	-265.	289.
$logS^F$ * logFOP	-168.	-165.	42.0	-469.	-66.9
$logS^P$ * logPOP	-286.	-285.	51.7	-427.	-173.
$logS^M$ * DEDB	-7.80e+003	-7.75e+003	1.32e+003	-1.16e+004	-4.66e+00
$logS^F$ * DEDB	9.94	0.000	13.1	0.000	31.1
$logS^P$ * DEDB	9.79	0.000	13.2	0.000	28.4
$logS^M$ * DIPRI	11.3	0.000	13.5	0.000	30.4
$logS^F$ * DIPRI	10.5	0.000	13.3	0.000	31.1
$logS^P$ * DIPRI	9.83	0.000	13.2	0.000	28.4
$logS^M$ * DLEGAL	6.57	0.000	11.7	0.000	30.4
$logS^F$ * DLEGAL	13.2	0.000	25.1	0.000	73.5
$logS^P$ * DLEGAL	4.70	0.000	10.4	0.000	28.4
TFPG	-0.0305	-0.0181	0.121	-0.999	0.451
TFP/Avr.TFP	-1.03	-0.735	1.47	-5.57	0.972
logSM * (TFP/Avr.TFP)	-28.1	-20.2	40.2	-154.	25.7
logSF * (TFP/Avr.TFP)	-26.5	-19.4	38.9	-121.	25.4
logSP * (TFP/Avr.TFP)	-32.3	-21.9	40.1	-123.	16.5

Table C.5 Summary Statistics of Dependent and Independent Variables for High-Income Countries

Variable	Mean	Median	Stand. Dev.	Min	Max
TFP	0.488	0.252	0.771	0.000650	3.50
$logS^M$	27.5	27.4	1.16	24.1	30.4

Table C.5 (continued)

$\log S^F$	27.3	27.5	1.10	22.5	31.1
$\log S^P$	27.6	27.8	0.545	25.6	28.4
logH	2.34	2.37	0.156	1.90	2.61
$\log S^M$ * logH	64.2	64.3	5.14	54.0	76.8
$\log S^F$ * logH	63.9	64.7	5.06	47.2	73.5
$\log S^P$ * logH	65.8	66.3	4.30	49.8	73.0
logMOP	-2.59	-2.68	0.743	-4.52	-0.927
logFOP	-5.28	-5.35	1.42	-13.1	-2.50
logPOP	-9.41	-9.25	2.25	-14.0	-6.47
$\log S^M$ * logMOP	-71.2	-73.6	20.8	-122.	-25.3
$\log S^F$ * logFOP	-141.	-143.	34.2	-297.	-66.9
$\log S^P$ * logPOP	-260.	-254.	62.2	-389.	-173.
$\log S^M$ * DEDB	17.5	26.6	13.1	0.000	29.6
$\log S^F$ * DEDB	16.9	26.6	13.3	0.000	31.1
$\log S^P$ * DEDB	17.3	27.3	13.4	0.000	28.4
$\log S^M$ * DIPRI	23.5	27.2	9.69	0.000	30.4
$\log S^F$ * DIPRI	23.0	27.2	10.0	0.000	31.1
$\log S^P$ * DIPRI	23.0	27.7	10.4	0.000	28.4
$\log S^M$ * DLEGAL	10.0	0.000	13.5	0.000	30.4
$\log S^F$ * DLEGAL	9.27	0.000	13.0	0.000	30.5
$\log S^P$ * DLEGAL	6.86	0.000	12.0	0.000	28.4
TFPG	-0.00840	-0.00967	0.0804	-0.403	0.236
TFP/Avr.TFP	-0.949	-0.411	1.80	-5.57	0.972
logSM * (TFP/Avr.TFP)	-25.9	-10.1	49.3	-154.	25.7
logSF * (TFP/Avr.TFP)	-23.1	13.6	46.6	-121.	25.4
logSP * (TFP/Avr.TFP)	-32.3	-45.7	47.6	-123.	16.5

Table C.6 Summary Statistics of Dependent and Independent Variables for Upper Middle-Income Countries

Variable	Mean	Median	Stand. Dev.	Min	Max
TFP	0.230	0.0384	0.391	7.06e-005	1.67
$\log S^M$	27.1	27.4	1.12	21.0	28.4
$\log S^F$	27.3	27.5	1.08	22.7	31.3
$\log S^P$	27.6	27.8	0.562	25.6	28.4
logH	2.21	2.26	0.204	1.47	2.49
$\log S^M$ * logH	60.0	60.9	5.63	38.6	69.4
$\log S^F$ * logH	60.2	61.5	6.04	37.0	73.3
$\log S^P$ * logH	61.7	63.0	5.93	38.8	69.3
logMOP	-3.57	-3.36	0.912	-7.01	-2.03
logFOP	-6.56	-6.34	1.34	-11.5	-3.70
logPOP	-10.7	-10.5	1.45	-15.8	-8.12

Table C.6 (continued)

$logS^M$ * logMOP	-96.7	-89.6	24.1	-187.	-57.2
$logS^F$ * logFOP	-174.	-171.	31.5	-313.	-104.
$logS^P$ * logPOP	-294.	-289.	38.7	-427.	-225.
$logS^M$ * DEDB	8.00	0.000	12.3	0.000	28.4
$logS^F$ * DEDB	7.46	0.000	12.2	0.000	31.0
$logS^P$ * DEDB	7.42	0.000	12.2	0.000	28.3
$logS^M$ * DIPRI	6.78	0.000	11.8	0.000	28.4
$logS^F$ * DIPRI	6.01	0.000	11.3	0.000	30.7
$logS^P$ * DIPRI	5.06	0.000	10.7	0.000	28.4
$logS^M$ * DLEGAL	5.40	0.000	10.8	0.000	28.3
$logS^F$ * DLEGAL	4.85	0.000	10.5	0.000	31.0
$logS^P$ * DLEGAL	4.17	0.000	9.90	0.000	28.3
TFPG	-0.0298	-0.0181	0.119	-0.702	0.451
TFP/Avr.TFP	-2.26	-2.38	0.803	-3.46	-0.204
$logS^F$ * (TFP/Avr.TFP)	-61.9	-66.4	23.0	-97.4	-5.23
$logS^P$ * (TFP/Avr.TFP)	-62.8	-67.2	24.3	-97.6	-5.23
$logS^M$ * (TFP/Avr.TFP)	-64.1	-72.2	34.8	-97.7	-5.30

Table C.7 Summary Statistics of Dependent and Independent Variables for Lower Middle-Income Countries

Variable	Mean	Median	Stand. Dev.	Min	Max
TFP	0.235	0.0612	0.341	7.43e-009	2.32
$logS^M$	27.1	27.2	0.659	24.9	28.4
$logS^F$	27.0	27.2	1.09	23.3	29.8
$logS^P$	27.6	27.8	0.483	26.0	28.4
logH	1.97	1.99	0.169	1.41	2.27
$logS^M$ * logH	53.6	54.2	5.03	35.8	63.1
$logS^F$ * logH	53.4	54.2	5.52	36.1	63.5
$logS^P$ * logH	54.2	54.8	4.78	41.7	63.1
logMOP	-4.14	-4.06	1.98	-10.0	10.2
logFOP	-7.08	-6.71	2.01	-15.8	8.78
logPOP	-11.3	-11.1	1.28	-15.1	-9.29
$logS^M$ * logMOP	-112.	-110.	54.3	-265.	289.
$logS^F$ * logFOP	-191.	-180.	46.7	-469.	-97.4
$logS^P$ * logPOP	-313.	-307.	36.4	-423.	-253.
$logS^M$ * DEDB	6.71	0.000	11.7	0.000	27.6
$logS^F$ * DEDB	6.21	0.000	11.3	0.000	28.4
$logS^P$ * DEDB	4.71	0.000	10.4	0.000	28.3
$logS^M$ * DIPRI	4.49	0.000	10.1	0.000	27.6
$logS^F$ * DIPRI	4.46	0.000	10.0	0.000	28.1
$logS^P$ * DIPRI	4.01	0.000	9.75	0.000	28.1

Table C.7 (continued)

$\log S^M$ * DLEGAL	4.53	0.000	10.1	0.000	27.6
$\log S^F$ * DLEGAL	4.00	0.000	9.58	0.000	28.1
$\log S^P$ * DLEGAL	3.29	0.000	8.98	0.000	28.1
TFPG	-0.0574	-0.0263	0.154	-0.999	0.163
TFP/Avr.TFP	-0.583	-0.634	0.324	-1.05	0.382
$\log S^F$ * (TFP/Avr.TFP)	-15.8	-17.4	8.81	-28.5	10.0
$\log S^P$ * (TFP/Avr.TFP)	-15.2	-16.2	9.22	-31.4	10.1
$\log S^M$ * (TFP/Avr.TFP)	-17.7	-20.2	9.54	-24.3	10.1

Table C.8 Correlation Matrix of TFP Convergence Model

No.	Variable	1	2	3	4	5	6	7	8	9
1	**TFPG**	1.0000								
2	***$\log S^M$***	0.0795	1.0000							
3	***$\log S^F$***	0.0372	0.4747	1.0000						
4	***$\log S^P$***	-0.0051	0.4407	0.5492	1.0000					
5	***logH***	0.0620	0.0049	0.1068	0.0759	1.0000				
6	***TFP/Avr.TFP***	-0.0846	-0.2189	-0.2087	-0.2265	-0.3545	1.0000			
7	***$\log S^M$ * (TFP/Avr.TFP)***	-0.0809	-0.2367	-0.2212	-0.2351	-0.3567	0.9997	1.0000		
8	***$\log S^F$ * (TFP/Avr.TFP)***	-0.1242	-0.2358	-0.2414	-0.2562	-0.3497	0.9988	0.9994	1.0000	
9	***$\log S^P$ * (TFP/Avr.TFP)***	-0.1328	-0.2295	-0.1955	-0.2346	-0.4577	0.9999	0.9999	0.9995	1.0000

D. TURKISH SUMMARY / TÜRKÇE ÖZET

Ekonomik büyüme, bir ülkenin kalkınmasını ve ilerlemesini ölçmek için kullanılan bir ölçümdür ve nüfus artış hızına, teknolojik uzmanlığa, tasarruf miktarına, kaynak dağılımına, ekonomik organizasyon yapısına ve diğer ilgili unsurlara bağlıdır. İktisatta, teknolojik ilerleme, ekonomik büyümenin temel itici gücü olarak görülmektedir.

Teknolojik ilerleme, "Yeni bilginin yaratılması, mevcut bilginin ekonomik açıdan önemli yeni ürün ve işlevlere dönüştürülmesi veya mevcut bilgiye yeni şekil verilmesi" olarak tanımlanabilir (Edquist, 1997, s.14). Bir ülkedeki teknolojik yeniliği veya ilerlemeyi ölçmek için çok çeşitli değişkeni analiz etmek gerekir. Bir ülkenin teknik ilerlemesini veya inovasyon seviyesini ölçmek için sıklıkla kullanılan göstergelerin birkaçı; Ar-Ge harcamaları, patent başvuruları, yüksek teknoloji ihracatı, teknolojik kapasite, insan sermayesi, inovasyon endeksi ve üretkenlik şeklinde sayılabilir.

Teknolojik ilerleme ve ekonomik büyüme ilişkisine yönelik hatırı sayılır miktarda literatür çalışması, teknolojik yeniliğin ekonomik büyümenin hayati bir itici gücü olduğunu tutarlı bir şekilde ortaya koymaktadır. Örneğin, Adam Smith'ten sonra ortaya çıkan büyüme teorileri, ekonomik büyümenin iş bölümü ve uzmanlaşmadan kaynaklanan verimlilik artışları yoluyla sağlanacağını öne sürmektedir. Bu teoriler, ekonomik büyümenin temel itici güçleri olarak teknoloji, Ar-Ge, yenilik, üretkenlik ve uluslararası ticaretin önemini vurgulamaktadır.

Ancak neoklasik teoride teknolojik gelişme genellikle dışsal bir faktör olarak ele alınmış ve büyümenin ana elementi sermaye birikimi olarak görülmüştür. Öte yandan içsel büyüme teorisi inovasyona dayalı büyüme kavramını ortaya çıkarmıştır. Ortaya çıkan içsel büyüme modelleri, kâr odaklı işletmelerin inovasyon çabalarının teknolojik ilerlemenin ve verimlilik artışının temel itici gücü olduğunu vurgulamıştır.

İçsel büyüme modelleri, ekonomik bir varlık olarak teknolojinin iki temel özelliğini vurgulamaktadır. Teknolojinin dikkate değer bir özelliği, birden fazla kullanıcının aynı anda kullanımdan yararlanabilmesini sağlayan rakipsiz olma özelliğidir. İkinci özellik ise, teknoloji getirilerinin özel ve kamusal bileşenlere bölünmesiyle ilgilidir. Bu ifade, teknolojinin yalnızca yerel ülkeler için kar sağlamakla kalmayıp, aynı zamanda teknolojiyi icat eden ülke dışındaki ülkelere de fayda sağlayan pozitif dışsallıklar da ürettiğini göstermektedir. Yani, uluslararası teknoloji yayılımı yoluyla, yeni teknolojiler ve yenilikler menşei ülkelerden bunları benimseyen ülkelere yayılabilir.

Gelişmiş ülkeler, yüksek vasıflı işgücü aracılığıyla kendi Ar-Ge çalışmalarını bağımsız olarak yürütme kapasitesine sahiptir. Sonuç olarak, gelişmiş ülkeler, yeni teknolojiler yaratma ve yenileme konusunda bir geçmişe sahip oldukları için yeni teknolojide ön sıralarda yer alırlar. Öte yandan, gelişmekte olan ülkeler yeni teknolojik uzmanlık yaratma becerisinden yoksundur. Tipik olarak yenilikçi faaliyetleri yürütmek için çok az kapasiteye sahiptirler ve bu faaliyetler, ileri becerilere sahip olmayan bir iş gücü tarafından yürütüldüğünde büyük ölçüde etkisiz kalır. Bu nedenle, bu ülkeler teknik ilerlemelerini artırmak için yabancı teknolojilere ihtiyaç duyarlar. Bu bakımdan, teknolojide öncü ülkelerden uluslararası teknoloji difüzyonu veya yayılımı gelişmekte olan ülkeler için oldukça önemlidir.

Teknoloji veya bilgi yayılımları genel olarak bireylerin veya kuruluşların kendi yenilikçi faaliyetlerinden kaynaklanan tüm avantajları tam olarak elde edemediği dışsallıklar olarak nitelendirilir. Teknolojik yayılma, firmaların başkaları tarafından üretilen bilgileri bir piyasa işlemi yoluyla ödeme yapmadan elde edebilmesi durumunu ifade eder. Bilginin yaratıcıları veya mevcut sahipleri, diğer firmaların elde edilen bilgileri kullanmasını engelleyecek hiçbir yasal araca sahip değildir. Yayılmanın bir diğer tanımı ise "Teknoloji yayılmaları, istemsiz sızıntının yanı sıra yararlı teknolojik bilgilerin gönüllü olarak paylaşılması anlamına gelir." (Steurs, 1995, s.2).

Grilliches tarafından 1979'da ortaya koyulan çalışma sayesinde, teknoloji yayılımlarına ilişkin iki açık kavram kesin olarak ortaya konmuştur: Kira yayılımları ve bilgi yayılımları. Tamamen ticaret veya yatırım gibi ekonomik işlemlerden kaynaklanan kira yayılmalarının aksine, gerçek bilgi yayılmaları ekonomik faaliyet gerektirmeyebilir. Bu ayrımdan dolayı, uluslararası bilgi yayılma kanalları doğrudan ve dolaylı kanallar olarak kategorize edilmektedir. En popüler dolaylı kanallar ithalat, ihracat ve doğrudan yabancı yatırımlardır (DYY) ve patentler, lisanslama faaliyetleri, teknik konferanslar veya bilimsel makaleler doğrudan kanallara örnek verilebilir.

Az gelişmiş ülkelerin ekonomik büyümesi için gelişmiş ülkelerden teknoloji yayılmalarının önemi göz önüne alındığında, bu yayılmaların nasıl oluştuğunu ve bu yayılmaların etkilerini analiz etmek önemlidir. Bu analizler, kişi başına düşen milli gelirdeki küresel eşitsizliklerin anlaşılmasına katkıda bulunmakta ve uluslararası pazarlara katılan gelişmekte olan ve geçiş sürecindeki ülkeler için değerli politika önerileri sunmaktadır.

Sonuç olarak ekonomik büyüme literatüründe teknoloji yayılım kanalları ve özellikleri önem taşımaktadır. Ülkeler arasındaki yayılma etkilerinin tahminine yönelik ampirik araştırma, Coe ve Helpman (1995) ile ortaya çıkmış ve daha sonra ülke, sektör ve firma düzeyinde birçok düzeyde kapsamlı araştırmalara yol açmıştır.

Ancak mevcut literatürdeki araştırmaların büyük bir kısmı çoğunlukla gelişmiş ülkelerdeki yayılma kanalları üzerine yoğunlaşmıştır. Az sayıda çalışma hem gelişmiş hem de gelişmekte olan ülkelerden oluşan bir grubu incelemiş olmasına rağmen bu ülkelerin gelişmişlik derecelerine göre bir ayrım yapmamıştır. Son zamanlarda bu farklılaşmayı inceleyen araştırmaların sayısı giderek artmaktadır. Bununla birlikte, gelişmekte olan ülkeleri analiz eden çalışmalara kıyasla hala daha fazla çalışma gelişmiş ülkeler üzerinde yoğunlaşmaktadır.

Dahası, ülkelerin ticaret modellerine, açıklık derecelerine, beşeri sermayeye, ülke içi koşullar dizisine ve coğrafi konumuna vb. bağlı olarak yabancı teknoloji yayılmalarından farklı faydalar elde etmesi muhtemeldir. Yani, bazı gelişmekte olan ülkelerin teknoloji yayılmalarından neden diğerlerinden daha fazla yararlanmış olabileceğine dair olası faktörlere ilişkin varsayımları gündeme getirmektedir. Bu araştırma aynı zamanda bu konuyu özellikle az gelişmiş ülkeler bağlamında ele almaktadır.

Ayrıca, teknolojik açığın, gelişmekte olan ülkelerin gelişmiş ülkeleri yakalama konusundaki ilerlemeleri üzerindeki önemli etkisi nedeniyle, literatürde teknolojik ilerlemenin bir göstergesi olarak toplam faktör verimliliğinin (TFV) yakınsaması kapsamlı bir şekilde incelenmiştir. Başka bir deyişle, üretkenlik düzeyindeki farklılıklar, ülkeler arasında kişi başına düşen gelirdeki farklılıkların önemli bir kısmını açıklamaktadır. Bu nedenle verimlilik yakınsaması, gelir yakınsamasının bir temsilcisi olarak görülebilir. Bu noktada teknoloji yayılımı ülkeler arasındaki teknolojik uçurumların eşitlenmesinde itici bir güç olduğundan, verimlilik yakınsaması kısmen dünya çapındaki teknolojik yayılımın boyutu tarafından belirlenmektedir.

Yukarıda bahsi geçen hususların hepsi bir araya getirildiğinde, "ülkeler arası büyüme oranlarının neden farklı olduğu" uluslararası teknoloji yayılımıyla yakından bağlantılıdır. Ancak literatürdeki pek çok çalışma öncelikle sanayileşmiş ülkelerde bu konuya odaklanmakta ya da farklı gelişmişlik düzeylerine sahip ülkeler arasında ayrım yapmamaktadır. Bu nedenle, bu tezin literatüre beklenen en büyük katkısı, gelişmekte olan ülkelere odaklanarak birçok uluslararası teknoloji yayılma kanalının üretkenlik üzerindeki göreceli etkilerini ve bu ülkelerin yabancı teknolojiyi özümseme kapasitesindeki değişiklikleri analiz etmesidir. Ayrıca, bu makale aynı zamanda üretkenlik yakınsamasında uluslararası teknoloji yayılımının rolünü de araştırmaktadır.

Bu amaçlara ulaşmak için iki farklı ekonometrik model oluşturulmuş ve tahmin edilmiştir. Bu senaryoda Türkiye'nin de aralarında bulunduğu 46 gelişmekte olan ülke ve G7 ülkeleri olan 7 gelişmiş ülke (Kanada, Fransa, Almanya, İtalya, Japonya, İngiltere ve ABD) seçilmiştir. Analiz 2000-2019 yılları arasını kapsamaktadır.

Bu analizlerde yenilikçi faaliyetin ölçüsü Ar-Ge stoklarıdır. Bir varsayım olarak, dünyadaki yenilikçi faaliyetin tek kaynağı G7 ülkeleridir; dolayısıyla, gelişmekte olan ülkelerdeki yurt içi Ar-Ge çalışmalarının TFV üzerindeki etkisi, bu ülkelerdeki yenilikçi faaliyetlerin nispeten az olması nedeniyle göz ardı edilmektedir.

Belirlenen gelişmekte olan ülkeler, Uluslararası Para Fonu (IMF), Birleşmiş Milletler (BM) ve Dünya Bankası'nın (WB) ülke sınıflandırmasına göre seçilmiştir. İlk olarak, BM'nin Dünya Ekonomik Durumu ve Beklentileri 2023 raporunda en az gelişmiş ülkeler (EAGÜ'ler) gelişmekte olan ülkeler listesinden çıkarılmıştır. Daha sonra bu ülke listesi IMF'nin yükselen ve gelişmekte olan ülkeler listesiyle karşılaştırılmış ve uygun görülen ülkeler eklenmiştir. Gelişmekte olan benzer ülkelere ulaşabilmek için bu ülkelerin G7 ülkeleriyle olan ticaret hacimleri, Ar-Ge harcamaları ve yurt dışı yerleşiklerin patent başvuruları da dikkate alınmıştır. Sonuç olarak seçilen 46 gelişmekte olan ülkeyi karşılaştırmak için bu ülkeler Dünya Bankası'nın gelir bazlı ülke sınıflandırmasına göre yüksek gelirli, üst orta gelirli ve alt orta gelirli ülkeler olarak sınıflandırılmıştır.

Kısa vadeli panel veriler kullanıldığından, tercih edilen tahmin yaklaşımı ağırlıklı olarak Rassal Etkiler modeli olmakla birlikte, gerektiğinde Sabit Etkiler tahmin modeli de kullanılmıştır. Ayrıca, sunulan hesaplamalar Gretl Sürüm 2021c programı kullanılarak yapılmıştır.

İlk model olan TFV modeli, farklı yayılma kanallarının göreceli etkisine ve ülkeye özgü bazı faktörlere odaklanarak, gelişmekte olan ülkelerdeki TFV'nin uluslararası teknoloji yayılımından nasıl etkilendiğini göstermeyi amaçlamıştır. Bu durumda, uluslararası teknoloji yayılım kanalları, sermaye malları ithalatı (dolaylı kanal), içeriye doğru DYY akışları (dolaylı kanal) ve patent başvurularıdır (doğrudan kanal). Bu model Coe, Helpman, ve Hoffmaister (2009) ile Seck (2009) çalışmalarının geliştirilmiş bir versiyonudur.

Temel model olan Denklem (1)'de, teknolojik ilerlemenin bir göstergesi olarak TFV bağımlı değişkendir ve sermaye malları ithalatı ile ağırlıklandırılmış yabancı Ar-Ge stoklarına veya G7 ülkelerinin yurt içi Ar-Ge stoklarına, içe doğru DYY akışları ile ağırlıklandırılmış yabancı Ar-Ge stoklarına ve patent başvuruları ile ağırlıklandırılmış yabancı Ar-Ge stokları ile insan sermayesine bağlıdır.

Ayrıca yukarıda bahsedilen ağırlıklandırma yöntemi, farklı uluslararası teknoloji yayılma kanallarını ve bu kanalların TFV üzerindeki etkisinin, gelişmekte olan ülkelerin G7 ülkeleriyle değişen ithalat, doğrudan yabancı yatırım ve patent ilişkisi hacimlerine bağlı olarak nasıl değiştiğini göstermek için kullanılmıştır. Bu ağırlıklar Coe ve Helpman (1995) makalesi baz alınarak oluşturulmuştur.

Daha önce de belirtildiği gibi bu tezin temel amaçlarından biri, teknoloji yayılma sürecinde gelişmekte olan ülkeler arasındaki heterojenliği ortaya koymaktır. Gelişmekte olan ülkelerin teknolojiyi uluslararası teknoloji yayılımından özümseme yeteneğini etkileyen, ülkeye özgü birçok faktör vardır. Bu faktörlerden biri de beşeri sermayedir. TFV üzerindeki doğrudan etkisinin yanı sıra, teknoloji yayılımı üzerindeki etkisi nedeniyle, beşeri sermaye ya da insan sermayesi TFV üzerinde dolaylı bir etkiye sahiptir, çünkü yabancı yüksek teknolojiyi anlayabilen ve onu yurtiçi kullanım için özümseyebilen kişi beşeri sermayedir.

Beşeri sermayenin yayılma sürecindeki rolünü değerlendirmek için modele yayılma kanalları ile etkileşim terimleri tek tek eklenmiştir. Daha sonra son denklem olarak, Denklem (2), tahmin edilmiştir.

Ülkelerin açıklığı (ticarete, doğrudan yabancı yatırımlara ve uluslararası patent başvurularına) bir ülkenin yabancı teknolojiyi özümseme kapasitesini etkileyen bir diğer önemli faktördür. Bu doğrultuda, Denklem (3)’te teknoloji yayılımları ile bir ülkenin açıklık derecesi arasındaki etkileşimin incelenmesi amaçlanmış olup, daha açık ülkelerin bu tür yayılmalardan elde edebileceği potansiyel avantajı göstermek hedeflenmiştir. Analiz kısmında, açıklık değişkenlerinin yayılma kanalı ağırlıklı yabancı Ar-Ge stokları ile etkileşim terimleri tahmin amacıyla modele tek tek eklenmiştir.

Kurumlar, ülkelerin yabancı teknolojiden ne ölçüde yararlandığını veya yayılma kazanımlarındaki heterojenlik kaynaklarını etkileyen bir diğer faktördür. Kurumların kalitesine ilişkin üç gösterge bu çalışmada dikkate alınmıştır: Dünya Bankası İş Yapma Kolaylığı Endeksi (EDB), Uluslararası Mülkiyet Hakları Endeksi (IPRI) ve yasal sisteminin tarihsel kökeni.

İlk kurumsal değişken EDB'dir. İş yapma kolaylığını değerlendiren Dünya Bankası endeksi, ekonomik kararları ve ekonomiyle mevcut veya potansiyel bağlantıları olan yerli ve uluslararası şirketlerin performansını etkileyebilecek çeşitli faktörleri kapsar. 2003 yılında tanıtılan endeks, hükümet kurallarına ilişkin içgörü sağlayan çeşitli yetki alanlarının kapsamlı bir göstergesi olarak hizmet etmektedir. Diğer hususların yanı sıra, sınır ötesi ticaretin kolaylaştırılması, yatırımcı haklarının korunması ve mülkiyetin tescili konularını da kapsamaktadır.

Analiz için, bu değişken tek yıllık bir kukla değişkeni olarak yayılma kanalı ağırlıklı yabancı Ar-Ge stokları ile etkileşim terimleri modele girmiştir. DEDB, ülkenin 2019'da EDB sıralamasında ilk 60'ta yer alması durumunda 1, aksi takdirde 0 değerini almaktadır (bkz. Denklem 4).

İkinci kurumsal değişken, mülkiyet haklarıyla ilgili kurumların gücünü değerlendiren IPRI tarafından temsil edilmektedir. Bu endeks kurumların mülkiyet haklarını, fikri mülkiyet haklarını ve yasal ve politik ortamı kapsar. Dolayısıyla bu endeks, uluslararası teknoloji yayılımında ülkeler arası heterojenliği de gösterebilir. IPRI puanları Levy-Carciente'nin (2019) Uluslararası Mülkiyet Hakları Endeksi 2019 raporundan alınmıştır. DIPRI, ülkenin 2019'da ilk 60'ta yer alması durumunda 1, aksi halde 0 değerini alan kukla bir değişken olarak modele dahil edilmiştir (bkz. Denklem 5).

Yasal Kökenler Teorisi, Fransız medeni hukukunu İngiliz medeni hukukuyla karşılaştırarak, birincisinin daha yüksek derecede hükümet mülkiyeti ve düzenlemesi ile karakterize edildiğini ve bunun da piyasalar üzerinde olumsuz etki olasılığını artırdığını öne sürmektedir. İngiliz ortak hukuku, gelişmiş yatırımcı koruması, azaltılmış hükümet mülkiyeti ve düzenlemesi ve daha az yapılandırılmış, daha özerk bir mahkeme sistemi ile bağlantılıdır. Üstelik çoğu ülkenin İngiliz ya da Fransız hukuk sistemlerine bağlı olması, ikisi arasında karşılaştırma yapılmasına olanak tanımaktadır. Bu nedenlerden dolayı, ülkelerin yasal sistemlerinin tarihsel kökeni bu analizde üçüncü bir kurumsal değişken olarak ele alınmıştır. Gelişmekte olan ülkelerin teknoloji yayılmalarını özümseme yeteneklerindeki heterojenliği açıklamada hukuk sistemlerinin tarihsel kökeninin potansiyel rolünü araştırmak için, modele ülkenin yasal kökeni İngiliz ise 1 değerini alan bir kukla değişken eklenmiştir (bkz. Denklem 6).

Temel modelin tahmin sonuçlarına göre, Tablo 7.2'de görüldüğü gibi, yüksek gelirli gelişmekte olan ülkeler için en güçlü yayılım kanalı, %99 düzeyinde anlamlı olan ve TFV'yi olumlu yönde etkileyen patent kanalıdır. Bu ülkelerde içe doğru DYY akışı kanalı aynı zamanda yabancı bilgi yayılımı sürecinde etkili olmaktadır; ancak yurt içi üretkenlik üzerindeki etkisi olumsuz ve daha zayıftır. Belirtildiği gibi, DYY'ler ile ilgili bilgi yayılımının olumsuzluğu, çokuluslu şirketler ile yerli firmalar arasındaki rekabetten kaynaklanabilmektedir. Doğrudan yabancı yatırım ve patent kanallarına rağmen, sermaye malları ithalatı uluslararası teknoloji yayılımının etkili bir kanalı değildir.

Üst-orta gelirli ülkelerde yerleşik olmayanların patent başvuruları teknolojinin yayılmasının en etkili yoludur. Ancak bu kanala ilişkin katsayının negatif bir değere sahip olduğunu ve bu durumun mevcut literatürde görülen beklenen işarete aykırı olduğunu belirtmekte fayda vardır. DYY aynı zamanda bu ülkelerde yabancı teknolojiyi yayan bir kanaldır, ancak istatistiksel anlamlılık düzeyi mütevazıdır ve negatif bir etkiye sahiptir. Ayrıca yüksek gelirli ülkelerde olduğu gibi bu gelir grubu ülkelerde ithalat kanalı etkisiz bir difüzyon kanalıdır. Ayrıca, yüksek gelirli ve üst orta gelirli gelişmekte olan ülkeler için, uluslararası teknoloji yayılma kanallarının göreceli önemi benzerlikler göstermektedir.

Düşük orta gelirli ülkelerde patent kanalı ve ithalat kanalının TFV üzerinde önemli etkisi bulunmakla birlikte, ithalat kanalı verimliliği olumlu etkilese de patent kanalı TFV üzerindeki olumsuz etkisine rağmen daha güçlü bir difüzyon aracıdır.

Beşeri sermayenin uluslararası teknoloji yayılımındaki dolaylı rolü, gelişmekte olan ülke sınıflandırmasına ve yayılma kanallarına bağlı olarak değişmektedir (bkz. Tablo 7.3, 7.4 ve 7.5). Beşeri sermayenin ithalat kanalından yabancı bilgi yayılımını nasıl etkilediğini gösteren SMH değişkeni tüm örneklemde etkili ve pozitiftir. Bu, insan sermayesinin, ithal edilmiş mallarla beraber gelen yabancı bilginin özümsenmesinde çok önemli bir faktör olduğu ve TFV'yi dolaylı olarak etkilediği anlamına gelir. Ancak yüksek, üst-orta ve alt-orta gelirli ülke grupları için beşeri sermayenin yurt içi üretkenlik üzerinde anlamlı bir dolaylı etkisi bulunmamaktadır.

İçeriye doğru DYY akışları ile insan sermayesi (SFH) arasındaki etkileşimin önemli olduğu ve tüm örneklemde TFV'yi olumlu yönde etkilediği sonucuna ulaşılmıştır (bkz.Tablo 7.4). Doğrudan yabancı yatırımlar (l_SF) kaynaklı yabancı bilgi yayılımının yurt içi üretkenlik üzerindeki olumsuz etkisi, yabancı teknoloji insan sermayesi tarafından işlendiğinde olumlu bir etkiye dönüşmüştür. Ayrıca, bu etkileşim teriminin varlığı yüksek gelirli ülkelerde istatistiksel olarak anlamlıyken, diğer iki gelişmekte olan ülke grubunda bu durum söz konusu değildir. Dolayısıyla, yüksek gelirli ulusların, beşeri sermayenin doğrudan yabancı yatırımlarla ilgili bilgi yayılmaları üzerindeki etkisi yoluyla TFV üzerindeki dolaylı etkisi sayesinde kendilerini üst orta ve alt orta gelirli ülkelerden farklılaştırabilecekleri ileri sürülebilir.

Diğer iki kanala benzer şekilde beşeri sermayenin patent kanalı (SPH) üzerinden TFV üzerindeki etkisi de örneklemin tamamı için benzer şekilde pozitif ve istatistiksel olarak anlamlıdır. Üstelik, doğrudan yabancı yatırım kanalında olduğu gibi bu faktör de yalnızca yüksek gelirli gelişmekte olan ülke grubu için ayırt edici bir yabancı teknolojiyi özümseme kapasitesi faktörüdür.

Ülkelerin ticarete, DYY'ye ve uluslararası patent başvurularına açıklığı, uluslararası teknoloji yayılımında ülkeye özgü bir diğer faktör olup, tüm yayılma kanalları (SMOP, SFOP ve SPOP) üzerindeki etkisi yoluyla tüm örneklem için TFV üzerinde olumlu bir etkiye sahiptir (bkz. Tablo 7.7, 7.8 ve 7.9). Bu durum, G7 ile ithalat hacmi daha yüksek olan ve G7'den daha yüksek DYY girişi ve patent başvurusu alan gelişmekte olan ülkelerin, yabancı teknoloji yayılımı yoluyla TFV'lerine daha fazla katkıda bulunabileceklerini göstermektedir. Bununla birlikte, gelişmekte olan ülke gruplarına ayrıntılı olarak bakıldığında, üst orta gelirli gelişmekte olan ülkelerde ticari açıklık yalnızca etkili faktör iken, DYY ve patent açıklığı yalnızca yüksek gelirli gelişmekte olan ülkelerde etkili bir heterojenlik faktörüdür.

Uluslararası bilgi yayılımı sürecinde EDB, ülkeler arasında yabancı teknolojiyi özümsemede olası bir diğer heterojenlik faktörüdür ve bu faktör de tüm örneklem için bütün yayılma kanallarıyla (SMDEDB, SFDEDB ve SPDEDB) etkileşimi yoluyla gelişmekte olan ülkelerin yurt içi verimliliğini olumlu yönde etkilemektedir (bkz. Tablo 7.11, 7.12 ve 7.13). Ayrıntılı olarak gelişmekte olan ülke gruplarına bakıldığında, daha elverişli kurumsal ortamlar, yüksek gelirli ve düşük orta gelirli ülkelerin yabancı bilgi içeren sermaye malları ithalatından ve DYY girişlerinden daha fazla yararlanmasına olanak tanırken; patent başvuruları ile gelen bilgi yayılmaları yalnızca yüksek gelirli ülkelere daha fayda sağlamaktadır.

IPRI tarafından temsil edilen fikri mülkiyet haklarının korunması, örnekteki gelişmekte olan ülkeler için ithalat, DYY ve patent kanalları yoluyla yabancı bilginin çekilmesinde olumlu bir belirleyicidir (bkz. Tablo 7.15, 7.16 ve 7.17). Bununla birlikte, IPRI'da yalnızca alt orta gelir grubunda daha üst sıralarda yer alan ülkeler için, uluslararası bilgi yayılımları TFV'yi tüm kanallardan etkileyebilmektedir. Yüksek gelirli ve üst orta gelirli ülkeler için IPRI'nin herhangi bir etkisi gözlemlenmemiştir.

Gelişmekte olan ülkeler arasındaki son heterojenlik faktörü, yasal sisteminin kökeni olup, İngiltere kökenli bir yasal sisteme sahip olan gelişmekte olan ülkelerde, tüm difüzyon kanallarından bilgi yayılımı TFV'ye olumlu katkı sağlamaktadır (bkz. Tablo 7.19, 7.20 ve 7.21). Ayrıca sadece alt orta gelirli ülkelerde ve patent kanalı için yasal sistem, teknolojinin uluslararası yayılmasını kolaylaştırmada rol oynamaktadır.

İkinci model olan TFV yakınsama modeli, Denklem (7), uluslararası teknoloji yayılımının TFV yakınsama sürecini nasıl etkilediğini göstermeyi amaçlamaktadır. Başka bir deyişle, yenilik yapmak yerine yabancı teknolojiyi taklit etmeyi tercih eden gelişmekte olan ülkelerin, teknolojik olarak gelişmiş ülkeleri, yani G7 ülkelerini yakalayıp, uluslararası teknoloji yardımıyla bu ülkeler arasındaki teknoloji açığını kapatabilecek olup olmadığını göstermektedir.

TFP yakınsama modeli Denklem (7), temel model olan Denklem (1)'in değiştirilmiş versiyonudur ve modifikasyon Maryam ve Jehan (2018) çalışması temel alınarak yapılmıştır. Bu modelde TFV büyümesi bağımlı değişken olup, sermaye malları ithalatına, içeriye doğru DYY akışlarına ve patent başvurusuna bağlı yabancı Ar-Ge stoklarına, insan sermayesine, TFV açığına ve yayılma kanallarının TFV açığı ile etkileşim değişkenlerine bağlıdır. TFV açığı, G7 ülkelerinin ortalama TFV'sinden örneklemdeki gelişmekte olan ülkelerin her birinin TFV'si arasındaki farktır.

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