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MASTER THESIS

**AN EMPIRICAL ANALYSIS OF THE IMPACT OF
INNOVATIVE ACTIVITIES ON PRODUCTION
AND EXPORT PERFORMANCE OF THE
TURKISH MANUFACTURING INDUSTRIES**

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ABSTRACT

AN EMPIRICAL ANALYSIS OF THE IMPACT OF INNOVATIVE ACTIVITIES ON PRODUCTION AND EXPORT PERFORMANCE OF THE TURKISH MANUFACTURING INDUSTRIES

HAKAN ÜNAL

The Turkish manufacturing industry has undergone a structural transformation that greatly affected its industrial production diversity, capacity, and competitiveness since the 1980s. At the same time, the manufacturing sector has become a critical component of the Turkish economy, which strives to pursue a more robust, powerful, and dynamic integration path with the world economy. However, the innovative and technological knowledge competence of the manufacturing industry did not reach a desired level, and even it was insufficient to build the competitiveness of the country over the years. The data, however, shows that the manufacturing industry and the Turkish innovation ecosystem have witnessed a significant increase in innovative activities since the beginning of the 2000s.

The main purpose of this thesis is to empirically investigate the impact of innovative activities on the production and export performance of the sub-sectors of the Turkish manufacturing industry. The way and the extent that innovative activities carried out show widespread heterogeneities across the sub-sectors of the manufacturing industry, and they are often closely related to the special characteristics of these sub-sectors. For each sub-sector, it can be argued that firms converge and cluster by demonstrating similar characteristics in resource utilization, qualification of workforce, production technology, even in innovative pursuits. However, the sub-sectors of the manufacturing industry differ significantly in terms of these characteristics, leading to observed inter-sectoral heterogeneities. Therefore, analysis that can not accommodate the information on sectoral heterogeneities leads to biased estimates. To handle sectoral heterogeneity adequately, this study employs sectoral analysis of the data related to the dependent and explanatory variables of the

production and export models. This research uses disaggregated annual data for each of the twenty-two sub-sectors of the Turkish manufacturing industry over the period 2009-2020. The production and export demand equations were estimated using the panel data fixed-effects method. The production model is considered as a function of capital, labor, and innovative activities, while the export demand model includes foreign income and relative prices and R&D expenditure representing the innovative activities of the sub-sectors. Alternatively, the number of R&D personnel was adopted as a specific innovation indicator to measure and report the impact of human capital involved in the research activities in the manufacturing industries.

The panel data analysis indicates that R&D expenditure has a positive impact on the sectoral production and export of the Turkish manufacturing industry. However, the empirical evidence presented by this research clearly shows that the impact of R&D on both production and export is quite limited and weak. R&D expenditure is more successful in explaining exports than production as it gets a higher coefficient in the export model. Interestingly, the number of R&D personnel seems to have no statistically significant impact in the cases of both sectoral production and export. Additionally, the regression results inform us about the impact of the remaining explanatory variables. Capital and labor, which are the traditional factors of production, are also found to contribute positively to sectoral production. The findings also show that an increase in foreign income and a decrease in relative prices positively affect sectoral exports.

Keywords: Turkish Economy, Manufacturing Industry, Innovation, Research and Development, R&D Expenditure, R&D Human Capital, Growth, Production, Export, Sectors, Fixed Effects Model

ÖZ

YENİLİKÇİ FAALİYETLERİN TÜRKİYE İMALAT SANAYİİNİN ÜRETİM VE İHRACAT PERFORMANSINA ETKİSİNİN AMPİRİK ANALİZİ

HAKAN ÜNAL

Türk imalat sanayi, 1980'li yıllardan bu yana endüstriyel üretim çeşitliliğini, kapasitesini ve rekabet gücünü büyük ölçüde etkileyen önemli bir yapısal dönüşüm geçirmektedir. Aynı zamanda imalat sektörü, dünya ekonomisiyle daha sağlam, güçlü ve dinamik bir entegrasyon yolu izlemeye çalışan Türkiye ekonomisinin kritik bir bileşeni haline gelmiştir. Ancak, imalat sanayiinin inovasyon ve teknolojik bilgi yetkinliği yıllar içinde istenilen düzeye ulaşmamış, hatta ülkenin rekabet gücünü inşa etmede yetersiz kalmıştır. Diğer taraftan, veriler imalat sanayi ve Türk inovasyon ekosisteminin 2000'li yılların başından itibaren yenilikçi faaliyetlerde önemli bir artışa tanık olduğunu göstermektedir.

Bu tezin temel amacı, yenilikçi faaliyetlerin Türk imalat sanayiinin alt sektörlerinin üretim ve ihracat performansı üzerindeki etkisini ampirik olarak araştırmaktır. Yenilikçi faaliyetlerin gerçekleştirilme şekli ve kapsamı, imalat sanayinin alt sektörleri arasında yaygın heterojenlikler göstermektedir ve bu heterojenlikler genellikle alt sektörlerin özel belirleyici nitelikleri ile yakından ilişkilidir. Her bir alt sektördeki firmaların; kaynak kullanımı, işgücü niteliği, üretim teknolojisi, hatta yenilikçi yaklaşımlarda benzer özellikler göstererek yakınsadıkları ve kümelandikleri söylenebilir. Diğer taraftan, imalat sanayinin alt sektörleri bu özellikler açısından önemli farklılıklar göstermekte ve sektörler arası heterojenlikler gözlenmektedir. Bu sebeple, sektörel heterojenlik bilgisini barındıramayan analizler yanlış tahminlere yol açmaktadır. Bu çalışma, sektörel heterojenliği yeterli düzeyde ele almak için, üretim ve ihracat modellerin bağımlı ve açıklayıcı değişkenlerine ilişkin verilerin sektörel analizini gerçekleştirmiştir. Bu araştırma, 2009-2020 döneminde Türk imalat sanayiinin yirmi iki alt sektörünün her birine ait ayrıştırılmış yıllık verilerini kullanmaktadır. Üretim ve ihracat talep denklemleri, panel veri sabit

etkiler yöntemi kullanılarak tahmin edilmiştir. Üretim modeli sermaye, emek ve yenilikçi faaliyetlerin bir fonksiyonu olarak ele alınırken, ihracat talebi modeli dış gelir, nispi fiyatlar ve alt sektörlerin yenilikçi faaliyetlerini temsil eden Ar-Ge harcamalarını içermektedir. Alternatif olarak, Ar-Ge personeli sayısı, imalat sanayiinde araştırma faaliyetlerinde yer alan beşerî sermayenin etkisini ölçmek ve raporlamak için bir diğer yenilik göstergesi olarak benimsenmiştir.

Panel veri analizi, Ar-Ge harcamalarının Türk imalat sanayiinin sektörel üretimi ve ihracatı üzerinde olumlu bir etkiye sahip olduğunu göstermektedir. Ancak, bu çalışmada sunulan ampirik kanıtlar, Ar-Ge'nin hem üretim hem de ihracat üzerindeki etkisinin oldukça sınırlı ve zayıf olduğunu açıkça göstermektedir. Ar-Ge harcamaları, ihracat modelinde daha yüksek bir katsayı aldığı için ihracatı açıklamada üretimden daha başarılıdır. İlginç bir şekilde, Ar-Ge personeli sayısının hem sektörel üretim hem de sektörel ihracat üzerinde istatistiksel olarak anlamlı bir etkisi olmayan bir sonuç ortaya koymasındır. Ek olarak, regresyon sonuçları bize diğer açıklayıcı değişkenlerin etkisi hakkında bilgi vermektedir. Geleneksel üretim faktörleri olan sermaye ve emeğin sektörel üretime olumlu katkı sağladığı tespit edilmiştir. Elde edilen bulgular dış gelirdeki artışın ve göreceli fiyatların düşmesinin sektörel ihracatı olumlu etkilediğini göstermektedir.

Anahtar Kelimeler: Türkiye Ekonomisi, İmalat Sanayii, İnovasyon, Araştırma ve Geliştirme, Ar-Ge Harcamaları, Ar-Ge Beşerî Sermayesi, Büyüme, Üretim, İhracat, Sektörler, Sabit Etkiler Modeli

PREFACE

In recent decades, the Turkish economy has attached great importance to the policies promoting knowledge, skills, and competencies for producing technology-intensive goods and products. Achieving this goal requires a solid and enduring approach to R&D and innovation, powered by the collaboration of the entire ecosystem. The manufacturing industry is a critical part of the innovation ecosystem as it transforms ideas and knowledge into tangible and valuable products. The main motivation behind this research is to understand how effectively the Turkish manufacturing industry performed in obtaining economic outcomes from its innovative activities. The importance of this study comes from the fact that it empirically tests the impact of innovative activities of the Turkish manufacturing industries on sectoral production and exports. This study, which primarily measures innovation through R&D expenditures, also considers the number of R&D personnel as an alternative innovation indicator in order to investigate the role of human capital in technology and knowledge production in the manufacturing industry.

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TABLE OF CONTENTS

ABSTRACT	ii
ÖZ.....	iv
PREFACE.....	vi
TABLE OF CONTENTS.....	vii
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF ABBREVIATIONS	xiii
INTRODUCTION.....	1

CHAPTER ONE THE IMPACT OF TECHNOLOGICAL CHANGE ON ECONOMIC GROWTH: A LITERATURE REVIEW

1.1. Introduction.....	9
1.2. The Impact of Exogenous Technological Change on Growth.....	10
1.2.1. The Solow Model (1956).....	11
1.2.2. The Ramsey-Cass-Koopmans Model (1965).....	17
1.3. The Impact of Endogenous Technological Change on Growth.....	19
1.3.1. Arrow (1962), Learning by Doing.....	21
1.3.2. The AK Model.....	22
1.3.3. Romer Model (1986), Knowledge Accumulation	25
1.3.4. Lucas Model (1988), Human Capital Accumulation.....	26
1.3.5. Romer (1990), Product Variety Model.....	27
1.3.6. Grossman and Helpman Model (1991), Quality Ladders.....	30
1.3.7. Aghion and Howitt Model (1992), Creative Destruction	31

1.3.8. Rivera-Batiz and Romer Model (1991), Foreign Trade, Integration and Openness.....	33
1.3.9. Segerstrom Model (1991), Imitation	34
1.3.10. Blomstrom and Wang Model (1992), Foreign Direct Investment.....	35
1.4. The Implications of Growth Theories	37
1.5. Literature Review of the Empirical Studies	42
1.5.1. Empirical Studies on the Relationship Between R&D Expenditure and Economic Growth.....	43
1.5.2. Review of Empirical Studies on the Relationship Between R&D Expenditure and Economic Growth for Manufacturing Industry	48
1.5.3. Empirical Studies on the Relationship Between R&D Expenditure and Export	54

CHAPTER TWO **THE GENERAL STRUCTURE AND THE TECHNOLOGICAL FEATURES** **OF THE TURKISH MANUFACTURING INDUSTRY**

2.1. Introduction.....	58
2.2. The Review of The Turkish Economy and Its Industrialization Process.....	59
2.2.1. The Turkish Economy in The Pre-1980 Period.....	60
2.2.2. The Turkish Economy in The Post-1980 Period	65
2.2.3. The Composition of Goods in Foreign Trade.....	69
2.2.4. Research and Development Activities.....	70
2.3. The General Structure of the Manufacturing Industry	72
2.3.1. Growth.....	72
2.3.2. Investment, Enterprises, and Employment	74
2.3.3. Production and Value-Added	77
2.3.4. Export and Import.....	79
2.4. The Technological Structure of the Manufacturing Industry.....	80
2.4.1. Classification of the Manufacturing Industry Sub-Sectors.....	81

2.4.2. Enterprises and Employment.....	83
2.4.3. Research and Development Activities.....	85
2.4.4. Patent Activities.....	88
2.4.5. Production and Value-Added	89
2.4.6. Export and Import.....	91
2.4.7. General Overview of the Section.....	94

CHAPTER THREE

AN EMPIRICAL ANALYSIS: THE IMPACT OF INNOVATION ON PRODUCTION AND EXPORT IN THE TURKISH MANUFACTURING INDUSTRY

3.1. Introduction.....	96
3.2. Empirical Models, Variables and Data	97
3.3. Methodology of Empirical Analysis	103
3.3.1. Panel Unit Root Test.....	103
3.3.2. Panel Data Estimation Methods	104
3.3.3. Model Selection Tests.....	107
3.3.4. Diagnostic Tests.....	109
3.4. Findings of Empirical Analysis.....	110
3.4.1. Unit Root Test Results.....	111
3.4.2. Model Selection and Regression Results.....	112
3.4.3. Robust Estimation Results.....	116
CONCLUSION.....	118
PREFERENCES	123
APPENDIX A	135
APPENDIX B	145

LIST OF TABLES

Table 2.1. Main Economic Indicators of The Turkish Economy (1930-1945).....	61
Table 2.2. Main Economic Indicators of The Turkish Economy (1946-1960).....	63
Table 2.3. Main Economic Indicators of The Turkish Economy (1960-1980).....	65
Table 2.4. Main Economic Indicators of The Turkish Economy (1981-2000).....	67
Table 2.5. Total R&D Expenditures of The Turkish Economy (2001-2020).	71
Table 2.6. The Share of Manufacturing Industry in GDP of Turkey (1998-2019).. ..	73
Table 2.7. Nace Rev.2 Classification and Technology Intensity Classification of Manufacturing Industry Sub-Sectors.	82
Table 3.1. The Sources of Data.	101
Table 3.2. Descriptive Statistics of The Variables	102
Table 3.3. Correlation Matrix of The Variables	102
Table 3.4. Unit Root Test Results.	111
Table 3.5. Model Selection Tests Results of The Production Model.....	112
Table 3.6. Model Selection Tests Results of The Export Demand Model.....	113
Table 3.7. Regression Results of The Production Model.....	114
Table 3.8. Regression Results of The Export Demand Model.....	115
Table 3.9. Robust Estimation Results.....	117

LIST OF FIGURES

Figure 1.1. The Steady State Diagram of The Solow Model.	14
Figure 1.2. The Effect of the Technological Change on Steady-State.	15
Figure 1.3. The AK Model Growth Dynamics.	24
Figure 2.1. Export and Import by Broad Economic Categories in The Turkish Economy (2000-2019).	69
Figure 2.2. Growth Rates of The Turkish Economy and Manufacturing Industry (1998-2019).	73
Figure 2.3. Fixed Investment and Capacity Utilization Rate in Manufacturing Industry (1998-2016).	75
Figure 2.4. Number of Enterprises and Number of Employees in Manufacturing Industry (2003-2019).	76
Figure 2.5. Foreign Direct Investment in Manufacturing Industry (2007-2019).	76
Figure 2.6. Production Index of Manufacturing Industry (2005-2019).	77
Figure 2.7. Production Value and Value-Added in Manufacturing Industry (2003-2019).	78
Figure 2.8. Export and Import of Manufacturing Industry (2000-2019).	80
Figure 2.9. Number of Enterprises in Manufacturing Industry by Technology Intensity (2009-2020).	83
Figure 2.10. Number of Employees in Manufacturing Industry by Technology Intensity (2009-2020).	84
Figure 2.11. R&D Expenditure of Manufacturing Industry by Technology Intensity (2009-2020).	86

Figure 2.12. Number of R&D Personnel in Manufacturing Industry by Technology Intensity (2009-2020).....	87
Figure 2.13. Number of Ph.D. and Master's Degree R&D Personnel in Manufacturing Industry by Technology Intensity (2009-2020).	88
Figure 2.14. Number of Domestic Patent and Utility Model Applications in Manufacturing Industry by Technology Intensity (2000-2020).	89
Figure 2.15. Production in Manufacturing Industry by Technology Intensity (2009-2020).	90
Figure 2.16. Value-Added in Manufacturing Industry by Technology Intensity (2009-2020).....	90
Figure 2.17. Export and Import of Manufacturing Industry by Technology Intensity (2009-2020).....	92
Figure 2.18. Foreign Trade Balance of Manufacturing Industry by Technology Intensity (2009-2020).....	93

LIST OF ABBREVIATIONS

ASEAN+3	: Association of Southeast Asian Nations + China, Japan and S.Korea
CBRT	: The Central Bank of the Republic of Turkey
EU	: European Union
EUROSTAT	: European Statistical Office
FDI	: Foreign Direct Investment
GDP	: Gross Domestic Product
GNP	: Gross National Product
ICT	: Information and Communication Technology
IMF	: International Monetary Fund
KOSGEB	: Small and Medium Enterprises Development Organization
NACE	: Statistical Classification of Economic Activities in the European Community
OECD	: Organisation for Economic Co-operation and Development
Ph.D	: Doctor of Philosophy
TTGV	: Technology Development Foundation of Turkey
TÜBİTAK	: The Scientific and Technological Research Council of Turkey
TURKSTAT	: Turkish Statistical Institute
TURKPATENT	: Turkish Patent and Trademark Office

INTRODUCTION

The thesis aims to evaluate the Turkish manufacturing industry's performance in innovative activities. The impact of innovative activities on the production and export of the Turkish manufacturing industry will be examined empirically through econometric analysis.

Following the industrial revolution, the world economy has experienced a new epoch of "modern economic growth" characterized by population explosion, rapid urbanization, division of labor and specialization, and rising income per capita for the entire world. Such economic growth depends on basic production inputs such as land, labor, capital, and technology, as well as social, economic, and political structures. However, modern times have also witnessed global inequality and the divergence of per capita income across countries. The central questions on this problem are: what is the source of inequality, what makes countries rich, and what makes them poor? In this respect, the sustainable development of economies has been the primary topic of interest. While early theories drew attention to traditional production factors emphasizing resource allocation and equilibrium mechanisms, later theories highlight the priority of knowledge, technology, and innovation.

In today's global and competitive world, innovation and technological capability have become the most critical determinant of economic growth and the welfare of societies. Advanced countries stay far ahead of other countries in this regard. On the other hand, developing countries have also begun to attach more importance to technology and knowledge. They have given importance to innovation-based growth strategies to catch up with developed economies. Rapid technological changes have also affected the conditions in international trade. Competition has shifted towards technology-intensive products rather than factor-cost oriented. In pursuit of competition, economies are increasingly adopting ways of generating new knowledge and innovative products. From this perspective, the need for a strong, sustainable, competitive, and technology-intensive economy emerges as a necessity rather than a choice for developing countries.

The significance of the manufacturing industry in today's economic conditions manifests itself in the following ways: with its rapid growth potential, the industry has a vital role in achieving economic development as the engine of generating new technologies. The industry takes its place at the center of the economy when a country moves to a technology-intensive production structure. The industry spreads technological dynamism to other sectors via externalities it creates. Product diversification based on innovation and supported by manufacturing activities feeds growth significantly. The manufacturing industry is a major source of employment and helps maintain the foreign trade balance. Building a wide range of competencies in manufacturing is critical to gaining a trading advantage globally. In addition, the integration of economies has greatly increased the premium of the manufacturing industries, particularly for those producing exportable kinds of goods. Domestic and international markets have the potential to offer a high demand for manufactured goods that provide novelty, utility, and value for customers.

There are two main theoretical approaches regarding the impact of technology and innovation on economic growth in the literature. The first is the neoclassical growth model developed by Solow (1956). The theory defines the economy through aggregate production function, which relates inputs to outputs. Technology is an exogenous part of this function and taken as a constant variable that does not differ for all units in the economy. Sectoral heterogeneity is not expected in terms of technological knowledge. In the short run, capital accumulation is the source of growth. In the long run, the growth rate will revert to the rate of technological progress determined exogenously outside of the economy. The second approach considers technology an endogenous component acquired and differentiated on a firm basis. This approach asserts that firms can gain a competitive advantage through innovation and R&D. Technological knowledge acquired and produced by firms makes the sectors heterogenous. For this reason, this research adopts the endogenous technological change approach in the empirical part of this study as it allows sectoral heterogeneity.

The approach of endogenous technological knowledge first appeared with the term *learning by doing*, coined by Arrow (1962). Technological knowledge is the

outcome of economic activities and acquired by workers and firms as a by-product of ordinary production activities. The production environment functions as an ever-evolving learning environment. The AK-type growth models underline that technological knowledge obtained from learning by doing diffuses throughout the economy via externalities and spillovers, leading to economy-wide increasing returns. As examples of the AK-type model, Romer's knowledge accumulation model (1986) and Lucas's human capital accumulation model (1988) perceive knowledge as a public good and attribute the source of long-term sustainable growth to the dissemination of this nonexcludable knowledge to the whole economy. On the other hand, the use of ideas and products obtained from technological knowledge could be restricted through intellectual property rights and the legal system so that they become partially excludable goods. In this way, firms are rewarded with monopoly power resulting from innovative, creative, and purposeful R&D efforts, establishing a significant competitive advantage. Incorporating firms' endogenous R&D efforts and imperfect competition into the growth framework began with Romer (1990). Romer recognizes the varieties of intermediate goods as the primary indicator of innovation and technological knowledge and as the source of long-run economic growth. Grossman and Helpman's Quality Ladders model (1991) focuses on the quality improvements of an existing product, emphasizing vertical innovations. The model argues that each product can be developed unlimited times, creating a leap in the quality of an existing product. Aghion and Howitt (1992) draw attention to fierce competition resulting from innovation. Improving the quality of products speeds up the process of creative destruction, generating the dynamics of long-run growth by causing firm entry and exit to the market.

The subject of has received substantial interest after the theoretical literature on endogenous technological change emerged. R&D activities have appeared in studies as the primary indicator of firms' efforts to acquire technological knowledge. A significant body of empirical research on the subject has investigated the contribution of R&D expenditures on growth and export and provided positive and significant evidence for the validity of the endogenous growth theory. However, the literature has primarily focused on the aggregate R&D spendings of a particular

country or a group of countries and has paid little attention to industry-level disaggregate analysis. The manufacturing industry sub-sectors are a cluster of firms that exhibit similarities in some respect, such as factor utilization, productivity, technology usage, competition in foreign trade, and innovative pursuits. Convergence within the sectors can also lead to inter-sectoral heterogeneity in the manufacturing industry. Depending on the production technologies that the sectors exploit, the utility, quality, variety, and novelty of the products differ across the sub-sectors of the manufacturing industry. The theory also emphasizes this diversity in innovative activities. Technological knowledge is attributed to the deliberate and purposeful efforts of firms and defined as a production component that differentiates firms, leading to the differentiation and heterogeneity of sectors. We were able to detect this sectoral heterogeneity through the data of R&D expenditures and patent activities. The Turkish manufacturing industry sub-sectors are quite heterogeneous due to these complex sectoral specificities. The aggregated studies do not take into account this sectoral heterogeneity as they focus on country-based analyzes. Besides, aggregate data analysis is subject to some economic and statistical deficiencies as they disguise too much information due to the lack of detailed and focused data. This study was conducted at a disaggregated industry level to deal with these deficiencies. The sectoral level disaggregated analyzes are expected to uncover the relationship between variables more accurately compared to aggregated ones since they narrowed the scope of research. In this way, heterogeneity across sectors is better taken into account and it is easier to examine the dynamics of change. To the best of our knowledge, the disaggregated studies specific to the manufacturing industry are very limited in the literature. The number of empirical analyzes on the subject dealing with the Turkish manufacturing industry is scarce and does not cover the research period of this thesis. There also remains a gap in terms of questioning the contribution of the innovative activities to production and export in the Turkish manufacturing industry, especially for recent activities.

The Turkish economy began to focus on export-oriented and competitive growth targets in the 1980s. Economic policies brought about radical changes in the structure of the economy and the industry as well. These new policies positively

contributed to the manufacturing industry's export and production. However, a competitive advantage based on knowledge and productivity could not be formed. The economy went through difficult times in the 1990s and early 2000s. Afterward, it has achieved a successful growth performance by maintaining macroeconomic stability. The steps towards R&D and innovation have occupied an important place in recent decades. Private and public sectors have transferred more resources to R&D activities, and R&D support programs were put into practice for the private sector to make firms more competitive. University-industry cooperation was encouraged, and the number of technoparks and R&D centers has boosted in recent years. Governmental organizations have implemented human resources development programs to have qualified researchers. While the overall R&D spending ratio to GDP was 0.53% in 2001, it doubled and reached 1.09% in 2020. In the same period, the Turkish economy's total R&D spending has increased 42 times, the number of R&D personnel has increased seven times.

The innovative activities in the manufacturing industry have progressed in parallel with the Turkish economy. In recent decades, the manufacturing industry's R&D expenditure and the stock of R&D personnel increased even more than the rates of the overall economy mentioned above. During the research period, R&D expenditures in the Turkish manufacturing industry, which were 2,014 million TL in 2009, increased more than ten times and reached 20,333 million TL in 2020. The number of personnel allocated to R&D also made a significant leap from 18,739 to 60,980. Since the production technologies make sectors heterogeneous in the pursuit of innovation, R&D intensity varies significantly between sectors and is not evenly distributed across the industry. Only five sectors made three-quarters of the R&D spendings. As expected, mostly medium-high and high-technology-intensive sectors have devoted the highest resources to R&D. A sizable part of the patent and utility model applications also originated from these sectors. Low technology-intensive sectors, which produce traditional commodities, had a high share in using labor and investment resources and in the quantity of output. They remained weak in innovative activities. The structure of these sectors needs to be transformed in a way that will bring competitiveness and high value-added production. To this end, despite

the heterogeneity of R&D spendings, the linkage between R&D investments, production, and export in the Turkish manufacturing industry is worth examining empirically. Exploring the possible benefits of these growing investments emerged as the main reason for conducting this research.

This thesis study uses disaggregated data of the industry. The coherence and compatibility of the data were decisive in determining our analysis period. The classification system of the manufacturing industry sub-sectors was changed in 2009 from NACE Rev 1.1 to NACE Rev.2, which introduces some new concepts at the section level. This transition made it impossible to make a general comparison between the current and the previous classification. For the consistency of the study, the empirical analysis covers the years between 2009-2020. We conducted a panel data analysis using annual data collected from 22 two-digit sub-sectors of the manufacturing industry. We consider R&D expenditure as the primary innovation indicator of the sub-sectors in the empirical part of this thesis. This study makes use of the production function and export demand function to compute the parameters of explanatory variables. Production function includes resources such as capital and labor that sectors use in production and R&D expenditures which reflect technological knowledge of the sectors. The export demand function consists of relative prices representing each sector's power of price competition and foreign income that does not contain sectoral variability. We added R&D expenditures representing the production technology of each sector to the function. Furthermore, the number of R&D personnel can also be used as an alternative innovation indicator of the sub-sectors. This study presents the regression results in which the number of R&D personnel is taken as a proxy of innovation in the appendix of this thesis.

The main benefit of this study is to explore whether the innovative activities carried out in the Turkish manufacturing industry contribute to industrial production and exports. There is sectoral heterogeneity in terms of the impact of innovative activities on production and exports. Aggregated studies do not take into account sectoral heterogeneity and presents statistical and economic deficiencies. This research uses disaggregated data of sub-sectors to better analyze and uncover the impact of innovative activities, taking into account sectoral heterogeneity. The

validity of the endogenous growth theory in the Turkish manufacturing industry will be questioned on a sectoral basis. The existing empirical knowledge in this field will be further enriched by the addition of the Turkish manufacturing industry. This thesis also differs from previous studies examining the impact of R&D activities on the production and export of the Turkish manufacturing industry in terms of the period it covers. The results will also report to what extent the traditional factors of production, capital and labor, contribute to sectoral production and will enable us to compare the contribution of these factors with that of R&D expenditures. Similarly, the export demand function will allow us to estimate the impact of foreign income, relative prices, and R&D expenditures on sectoral export and enable us to make a comparison between them. This study also considers the number of R&D personnel as an alternative innovation indicator and presents empirical results on the efficiency of human capital working in the field of R&D in the Turkish manufacturing industry.

The content of the thesis study is structured as follows: The first chapter examines economic growth models in the literature in terms of the source of technological change and provides a theoretical background on the subject. First, the growth models that address technological change as exogenous will be briefly discussed. Subsequently, endogenous growth theories will be presented, where technological change is driven by deliberate research activities of firms, externalities, knowledge spillovers, and learning by doing. This chapter also provides a background on some of the previous empirical works on the subject.

The second chapter first provides an overview of the industrialization phases of the Turkish economy by dividing it into the pre-1980 and the-post 1980 periods, distinguished based on policy implementations. Then, the general structure of the Turkish manufacturing industry is conveyed with tables, charts, and comments using some basic indicators. Afterward, to address the technological structure of the industry, sub-sectors are classified as low, medium-low, medium-high, high technology sectors according to their technology intensity. Some selected structural and innovative indicators are presented accordingly.

The third chapter of this study is devoted to the empirical estimation of the impact of innovative activities on production and export in the Turkish manufacturing industry. The production function and the export demand function are the models that provide the theoretical basis for this empirical study and enable us to perform the econometric analysis. The variables and data sources related to the models, panel data methodology, diagnostic tests, regression results, and findings are presented in this chapter.



CHAPTER ONE

THE IMPACT OF TECHNOLOGICAL CHANGE ON ECONOMIC GROWTH: A LITERATURE REVIEW

1.1. Introduction

The main objective of this chapter is to review the theoretical and empirical literature on the relationship between technological change and economic growth. It is widely accepted that the productivity and competitiveness of modern economies are shaped considerably on the grounds of technological knowledge. The ability to produce technology and to use it effectively provides significant dynamism and growth potential to an economy. In this regard, technological change is receiving growing importance and stands out as the primary component of production. Therefore, it is necessary to examine the connection between economic growth and technological change.

Over time a vast amount of theoretical literature is accumulated on the relationship between technological change and economic growth. These theories attempt to explain the source of inequalities in productivity and per capita income across countries and to uncover the role of technology and knowledge in the emergence of these disparities. Theoretical approaches related to the thesis subject can be classified as exogenous and endogenous technological change. Technological change is regarded as an external factor in the exogenous growth models and the sole indicator determining long-term growth. On the other hand, all other variables, except technology, affect economic growth only in the short term. In the endogenous growth models, technological change is dynamically produced within the economic system and associated with the efforts of economic actors, contributing to sustainable long-term growth together with all other production factors. Theoretical studies draw attention to different channels that explain how firms produce and acquire technology endogenously. These channels can be listed as follows: learning by doing, knowledge accumulation, human capital accumulation, research and

development activities, increasing the existing product quality and variety, openness to international trade, foreign direct investments, and imitation. These are considered as specific endogenous growth models in the literature.

The rest of this chapter is organized as follows. The following section begins with exogenous growth models, particularly focusing on the theoretical framework of the Solow model and the Ramsey-Cass-Koopmans model, and reviews the components, dynamics, and implications of these models. Section 1.3 explores the existing literature on endogenous growth theory and reveals various technology acquisition attitudes. In particular, this part covers the following growth models: AK-type model, Lucas' model, Romer's models (1986 & 1990), Aghion and Howitt's model, Grossman and Helpman's model, Rivera-Batiz and Romer's model, Segerstrom's model, Blomstrom and Wang's model. Section 1.4 summarizes the implications of the growth theories discussed in the previous section. The last section of this chapter reviews the empirical studies on the relationship between innovation, economic growth, and export.

1.2. The Impact of Exogenous Technological Change on Growth

The origin of technological change is of great importance in terms of its impact on the economy. In this respect, the exogenous growth theory advocates a strong proposition about the source of this change by asserting that technological change is formed outside the economic system independently of the decisions of all economic entities. Technological change emerges as an outcome of scientific studies apart from economic activities and recognized as the main source of long-term sustainable growth, affecting the efficiency of all economies across the world. In this way, the technological change eliminates the effects of the law of diminishing returns and allows the economy to grow at a rate equal to the rate of technological change.

Exogenous technological change is modeled within an economic environment that exhibits the following assumptions: (i) The perfect competition market is dominant in the economy, and plenty of homogenous firms operate in this economy, (ii) Production factors, capital and labor, are subject to the law of diminishing

returns, (iii) The aggregate production function is subject to constant returns to scale, (iv) As an exogenously provided public input, knowledge and technology are available to every firm and agent, (v) Firms are assumed to exploit the entire stock of technology without paying any cost. Economies perform under these conditions and focus on the capital accumulation process to increase worker's productivity. The models presented in this section explain how the growth mechanism works in the market structure mentioned here.

1.2.1. The Solow Model (1956)

Robert Solow made one of the most important contributions to economic growth literature. He analyzed the changes in the output level through aggregate production function. The main components of Solow's growth model are capital accumulation, population, and technological change. Since the labor supply grows at a constant rate, it is necessary to accumulate capital to generate more per capita production. In the short run, a steady growth path can be maintained without exogenous technological progress with a constant increase in capital, labor, and output. However, the economy needs exogenous technological change for sustainable long-run economic growth. In this respect, the model he constructed is classified as an exogenous growth model.

An essential feature of the Solow model is that the complex structure of the economy is depicted in the simplest and abstract way (Acemoglu, 2009, p.26). Solow developed his model in an economic structure where the perfect competition assumption and the price mechanism work effectively in the market and the supply-demand equilibrium is achieved through this mechanism. The economy internally achieves a stable and balanced equilibrium adjusting constant supply-demand equilibrium all the time. In the closed economy, the aggregate demand is equal to total income and both are determined by total output or production (Y). The aggregate demand is distributed to consumption goods (C) and investment goods (I).

As a supply-driven model, the model is developed based on the two equations, the production function and the capital accumulation function. The

production function is assumed to have the Cobb-Douglas form. Y is total production, K stands for capital, L stands for total employment and “ a ” represents output elasticity of capital and gets a value between 0 and 1. A represents technology or productivity parameter at any time.

$$Y = A_t F(K^a, L^{1-a})$$

This production function exhibits constant returns to scale. Increasing labor and capital inputs at the same percentage will increase output proportionally. Since each production factors, capital and labor, is subject to the law of diminishing returns (because $a < 1$), the marginal product of capital and labor will decline over time, and the additional capital or labor allocated to production produces less output.

The aggregate production function formulates how inputs, capital and labor, are transformed into output. Technology (A) is an exogenous factor that increases the efficiency of production factors and basically a shifter of production function (Solow, 1956, p.66-85). Capital refers to the number of physical inputs used in the production process and is the most crucial input of the model, as it improves the productive capacity of workers. Labor input stands for the workforce employed in the production. The growth rate of the population, and thus labor supply is assumed fixed and exogenous. Another assumption of the model, the substitution of capital and labor, implies that the production technique might change due to the fluctuations in the relative prices of labor and capital in perfectly competitive market conditions (Barro & Sala-i Martin, 2004, p.17).

There are many firms in the economy and they are price takers. These profit-maximizing firms have to solve this problem:

$$\max F(K, L) - rK - wL$$

Each unit of labor receives a wage represented as w , the price is paid for each unit of capital represented as r . Firms will use these factors in production until the marginal product of capital equals the rental cost of capital and the marginal product of labor equals the wage paid to workers (Jones & Vollrath, 2013, p.22-23).

$$w = \frac{\partial F}{\partial L} = (1-a) \frac{Y}{L}, \quad r = \frac{\partial F}{\partial K} = a \frac{Y}{K},$$

An important result of the assumption of the constant returns to scale to production function is that all the revenue obtained from total production will be distributed to capital and labor in proportion to their contribution. Thus, there are no economic profits in this model (Jones & Vollrath, 2013, p.22-23).

$$wL + rK = Y$$

The second key equation of the Solow model is the capital accumulation function that describes how capital accumulates. The change in the capital stock (ΔK) is obtained by subtracting the depreciation amount (θK) of the existing capital stock from the amount of total investment (sY). The depreciation rate (θ) of the capital stock is taken as a constant rate (Jones & Vollrath, 2013, p.24-25).

$$\Delta K = sY - \theta K$$

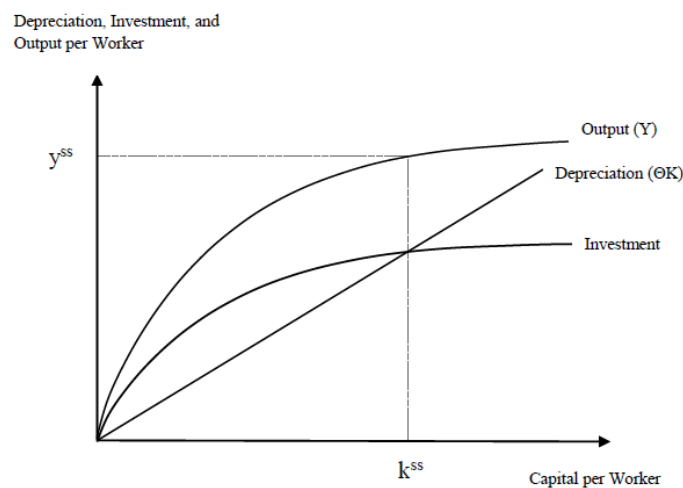
Capital is the outcome of firms' investment decisions and depends on household savings, a constant fraction of their income. In a closed economy, savings are equal to investments, and the only way to accumulate capital is to generate savings (Jones and Vollrath, 2013, p.24-25).

$$sY = S = I$$

Capital accumulation can accelerate economic growth only in the short run. Because of the law of diminishing returns to capital, capital owners will realize that the return on capital wanes over time and capital reaches its maximum level in the economy, and the accumulation process terminates. This is where the economy ends up with steady-state equilibrium under the existing technology and population dynamics. Both capital yields and labor wages stagnate at this level. In the short run, the growth only will take place during the transition path to this steady-state. Without any technological progress, the wealth and prosperity of society will eventually come to an end (Weil, 2013, p.66-67).

Figure 1.1. illustrates the relationship between investment, capital depreciation, and output in a steady-state level of the economy. The output curve is a downward sloping curve because of the diminishing returns to capital. The economy generates as much income as output and a constant fraction of this income is saved. Since these savings determine the investment amount, the investment curve is shaped similarly to the output curve. The depreciation curve is a function of the investment curve at a fixed rate. The steady-state level corresponds to the point where capital depreciation and the amount of investment produced by the economy intersect depicted as k^{ss} . If the capital per worker is below the steady-state level, the amount of investment will be greater than the amount of capital depreciation. This phase indicates a *capital deepening* process in which capital per worker increases in the economy. If the capital per worker is above the steady-state level, the amount of investment will be lower than the amount of capital depreciation. The capital stock will drop until reaching equilibrium at the steady-state level. The Solow growth theory posits that economies always move towards this steady-state equilibrium point in the short run (Weil, 2013, p.56-60).

Figure 1.1. The Steady State Diagram of The Solow Model.



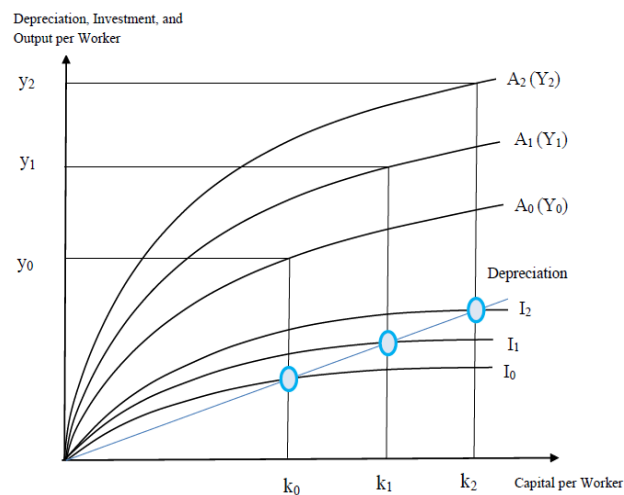
Source: Weil (2013)

The economy can only achieve sustainable per capita income growth by exogenous technological progress. Exogenous technological change alters the stable condition of the economy and ensures sustainable long-run growth by eliminating the

law of diminishing returns to capital. The exogenously developed technology is considered a public good and available to all firms and individuals. Firms do not have to bear any costs while using this technology. Once any invention, technology, or knowledge becomes public, the whole economy knows how to utilize it and firms can benefit from it in their production process (Acemoglu, 2009, p.28).

Figure 1.2. illustrates the effects of technological change on the level of output per worker. Technology (A) is a productivity parameter that grows at a constant rate over time. An increase in the level of technology from A_0 to A_1 to A_2 will shift up the production level of the economy as a whole from Y_0 to Y_1 to Y_2 , and simultaneously investment level of the economy from I_0 to I_1 to I_2 . The upward shifting investment curve will change the intersect point of capital depreciation and the amount of investment produced by the economy, thus changing the equilibrium level of steady-state, shifting it from k_0 to k_1 to k_2 . After all, the output per worker (y_0, y_1, y_2) and the capital per worker (k_0, k_1, k_2) increase together with the steady-state level at the same rate of technological change (Greenhalgh & Rogers, 2010, p.223-224).

Figure 1.2. The Effect of the Technological Change on Steady-State.



Source: Greenhalgh & Rogers (2010)

An important implication of the Solow model is that there will be convergence in the growth rates of countries in the long run. Technology will diffuse

across all countries and reduce the existing gap of growth rates between developed and less developed ones. When countries first initiate to accumulate capital, the marginal product of capital will be extremely high. For this reason, the growth rate of less-developed countries will inevitably be much higher than that of developed ones. Eventually, less-developed countries will catch up to the developed economies in their per capita income. This is named the process of *absolute convergence* across countries. On the other hand, countries with similar fundamental economic conditions in technology, savings rate, depreciation rate, and population growth rate will converge toward the same steady-state level. This indicates that similar countries will converge towards the same long-run per capita income. This is called the *conditional convergence* process across a certain group of economies (Aghion & Howitt, 2009, p 29-31).

The success of Solow's model is that it establishes a model in which the long-term growth equilibrium is achieved only by exogenous technology. In the short run, it foresees a balanced growth path in which capital stock, labor supply, and production grow at a constant rate (Jones & Vollrath, 2013, p.36-39). The model also strongly examines a country's growth path and explains how it will move up and down under the influence of factors such as thrift and fertility. The most important weakness of the model is the lack of explanation for the rate of technological progress, which the model takes as an undefined process containing scientific inventions and the diffusion of these inventions across the world (Aghion & Howitt, 2009, p 39). Although technology is the central component in Solow's model, the model left it unmodeled and failed to explain the technological differences across countries. In the mid-1980s, the exogenous technological approach was found to be insufficient to explain the substantial and ongoing growth differences of countries and unsatisfactory to analyze the sources of long-term growth (Barro & Sala-i Martin, 2004, p. 31).

1.2.2. The Ramsey-Cass-Koopmans Model (1965)

The Ramsey - Cass - Koopmans model originates from Ramsey's work published in 1928. Ramsey was interested in consumer behavior to find out optimal savings and consumption structure. Cass and Koopmans incorporated Ramsey's analysis into their growth models in 1965 (Barro & Salai Martin, 2004, p.18). Even though the model presents a notable amount of similarities with the Solow model, it also shows an important and distinctive feature. The Ramsey-Cass-Koopmans model focuses on the change in consumer behavior and analyzes the growth from a micro perspective by endogenizing the saving decisions of households.

Contrary to Solow's model, this model does not take savings as a constant fraction of the household's income. It establishes a micro-based growth model on the basis of households' utility optimization problems. The model assumes a representative household framework in which identical households have the same preferences, efficiency and wage rates (Barro & Salai Martin, 2004, p.86). The households are the source of the labor supply. They provide the workforce to the economy and receive a wage income at each time. They also receive interest income from firms in return for their savings.

Each household should solve a continuous optimization problem by deciding how much they will consume at any given date and how much they will set aside for savings to contribute to the accumulation of capital. When maximizing their lifetime utility, they are subject to budget constraints and inclined to change their saving rate over time by choosing the most appropriate spending and saving structure (Aghion & Howitt, 2009, p.31-32). The budget constraints of the representative household can be expressed as follows: The present value of the utilities from lifetime consumption cannot exceed the total value of the initial wealth plus the present value of the future income. The household has an instantaneous utility function: $u(c_t)$ that represents the consumption of each member of the household at time t . Consumption and saving decisions are shaped depending on the interest rate and discount rate. The discount rate describes the value that the household gives to present consumption. A high-interest rate will increase the tendency to savings; in contrast, a high discount rate

will increase the tendency to consume. Between these two effects, households balance their consumption and savings. The Ramsey-Cass-Koopmans model assumes that marginal utility is positive and decreases over time. Households also take into account future utilities in an infinite time horizon and choose the optimal combination of consumption and saving that maximizes their lifetime utility (Aghion & Howitt, 2009, p.32-33; Romer, 2012, p.52-57).

While the determination of the consumption and saving structure is different from the Solow model and somewhat complicated, the supply function, firm's behavior, and market conditions are relatively simple and the same as in the Solow model. Many identical firms operate in a competitive market and each firm has the same production function:

$$Y = F(K, AL)$$

The production function satisfies the same assumptions: constant returns to scale in production (Y) and diminishing returns to each production factor (K, L). Competitive firms use capital and labor so as to produce output and pay wages and rent in proportion to their marginal products. Firms sell their products in a competitive output market and are subject to profit-maximization problems. Firms pay a price for renting a unit of capital equals the marginal product of capital and firms employ workers until real wage equals the marginal product of labor. Firms earn zero profit in this model because of the constant returns to scale and competitive market economy (Romer, 2012, p.49-51).

Technology (A) is considered exogenous and grows at a certain rate over time, increasing the productivity of the whole economy. The effect of technology on the efficiency of the economy takes place through the labor force. Each worker becomes more efficient with the same amount of capital due to the change in technology. When we replace the constant number of labor inputs with an increasing number of efficiency units, the marginal product of capital grows indefinitely. The law of diminishing returns is balanced by the continuous rise in productivity thanks to the efficiency of the workforce and exogenous technology (Aghion & Howitt, 2009, p.31-38).

Unlike the Solow model, The Ramsey-Cass-Koopmans model suggests that economic policies can be followed to influence growth by directing the saving preferences in the short run. However, in the long run, the model reaches the same conclusion as Solow: the long run growth can not be achieved with capital accumulation, it is achieved only by exogenous technological progress and the model maintains the conditional convergence hypothesis (Aghion & Howitt, 2009, p.32).

1.3. The Impact of Endogenous Technological Change on Growth

Until the mid-1980s, the assumption that long-term growth is determined by exogenous technology developed outside the economy, had gained a strong place in the literature. However, the fact that the technology parameter could not be explained economically was seen as an important deficiency. Moreover, incorporating technological change into the growth model was a challenging problem as it restricts the fundamental competitive assumption of exogenous growth theory. For this reason, researchers have attempted to provide economic reasons for why firms invest in technological change and innovation, and focused on the modeling of endogenous technological change.

In terms of abandoning diminishing returns, endogenous technological change includes themes such as innovation, ideas, and knowledge, all of which imply the presence of increasing returns. When knowledge and ideas occupy a place in the growth models as a factor of production, innovative firms no longer act under perfect competition. They act under the monopolistic power they have gained through new ideas and technology. If the production function exhibits constant returns to scale, there would be no reward to innovators and firms in return for their efforts to produce new ideas and technology. All output would belong to capital and labor in proportion to their marginal product, leaving nothing for technological knowledge. Therefore, the endogeneity of technology can not be modeled based on the theory of competitive equilibrium.

The endogenous growth theory claims to explain current income variations among countries by establishing a link between economic growth and endogenously

produced technological change. The endogenous growth theory essentially postulates that even if economies reach high per capita income levels, they can still maintain high and increasing growth rates today and in the future. Therefore, they will not get stuck in a certain steady-state income. The per capita income gap between countries will exist at any time. Due to the dynamics of economies, income disparities can arise from various endogenous factors such as learning by doing, knowledge accumulation through physical capital or human capital, engaging in innovation and R&D activities, trade and openness, imitation, and foreign direct investment. To better understand the theory, examining how innovation and technological change are handled in the endogenous growth literature is necessary.

In this part of the chapter, the models considered to provide significant contributions to the endogenous growth literature will be examined. Initial endogenous growth models focus on factor accumulation, learning by doing, and knowledge externalities, forming the basis of the endogenous growth approach. These models are identical in the following features: technological change is gained either from unintended side effects of production activities or acquired through externalities. They perceive knowledge as a public good showing nonrival and nonexcludable good properties and consider it a production input provided by the efforts of private firms to public use. All firms can take advantage of these knowledge spillovers without paying any cost. Arrow's learning by doing, Romer's knowledge accumulation, and Lucas' human capital accumulation models are part of this set of endogenous growth models. The subsequent endogenous growth models focus on creativity and innovation and suggest that firms acquire knowledge and technological change through their deliberate research and development efforts. The technology and knowledge are treated as a private good showing nonrival but partially excludable good properties. With the help of the legal system and intellectual property rights, innovators who produce technology and knowledge can limit the use of the knowledge by other people and firms. The models that pay attention to innovation and R&D as the core component are Romer's product variety, Aghion and Howitt's creative destruction, and Grossman and Helpman's quality ladders model. After examining R&D-based endogenous growth models, we will

also review Rivera-Batiz and Romer's trade, integration and openness model, Segerstrom's imitation model, and Blomstrom and Wang's foreign direct investment model as different ways of acquiring technology and knowledge.

1.3.1. Arrow (1962), Learning by Doing

Arrow made a significant contribution to the development of the endogenous growth theory with *learning by doing*. His approach was recognized as a substantial attempt to endogenize technological change and a forerunner of the endogenous growth models that would come after him. Although Arrow did not transform his approach into an economic growth model, his work has been admired as an influential study in the endogenous growth literature. Arrow rejected the idea that the capital/labor ratio is the sole indicator that accounts for the increase in per capita income of countries. According to him, even though countries have similar natural endowments, they have distinctive production potentials due to the variations in their knowledge acquisition capabilities (Arrow, 1962, p.155-172).

Arrow emphasizes new knowledge acquisition, which he defined as the outcome of the worker's experience in the production process and referred to it as a learning activity. He came up with the term *learning by doing*, asserting that technical change is achieved through an internalized learning process rather than an external impact from outside the economic environment. In other words, workers and firms acquire new knowledge as a by-product of ordinary production activities or gain it while trying to solve a problem. The production environment shows up the performance of sustaining such an ever-evolving learning process with its dynamic structure. From this point of view, it is understood that firms are able to expand their production capacity by learning how to produce faster and better using existing labor and capital. This process never ends and makes steady growth possible (Arrow, 1962, p.155-172).

Knowledge is not limited to those who produce it. At this point, the spillover effect emerges as a beneficial factor and spreads and widens the ground of new knowledge and ideas. The increasing returns accomplished with the help of learning

by doing, and externalities will not cause troubles in the equilibrium mechanism since knowledge is publicly known, and no payment will be required for it. Because knowledge production is closely related to the stock of capital and the amount of output, a firm's productivity can be expressed as an increasing function of total investment and output in the economy. As a result, it makes sense to conclude that learning is a phenomenon that grows over time as firms continue to operate and workers gain more experience, thereby creating intertemporal changes in all production functions of the general economy (Arrow, 1962, p.155-172).

1.3.2. The AK Model

The AK model is the simplest way of explaining the effect of endogenous technological change on the growth mechanism. The model has a substantial proposition that endogenous investment rates make a difference to achieve a high growth rate and long-term sustainable growth without waiting for exogenous technological change. Past investments give rise to the emergence of new knowledge, learning, and technological change that could prevent the law of diminishing returns to capital. An important and alternative way to sustain high growth rates is to save a high fraction of income. These savings will finance technological progress (Jones & Vollrath, 2013, p.216-218).

The AK production function is a special case of Cobb-Douglas production function with constant returns to capital: ($Y = A K^a L^{1-a}$)

In this special case, when the output elasticity of capital is taken as $a=1$, there will be constant returns to capital. The resulting production function as follows: $Y=A K$ (Jones & Vollrath, 2013, p.216).

K has some composite definitions of capital, including physical and human capital. The model does not explicitly distinguish between capital accumulation and technological progress. A is a positive constant representing the technological knowledge for which the model does not explain its origin. It is a critical assumption that knowledge is gained serendipitously as a by-product of the capital accumulation process and offsets the tendency for the marginal product to diminish. The aggregate

production is a linear function of the capital stock, and the marginal product of capital is constant. For this reason, each additional new unit of capital will yield the same marginal product as the existing capital (Barro & Sala-i Martin, 2004, p.63).

We can obtain per capita output and capital-labor ratio from the production function:

$$y=Ak$$

All of the income obtained from output is not completely consumed, some of them are saved by individuals with a fixed rate and the savings of people is invested by firms:

$$Y=C+S, sY=I$$

The capital accumulation equation is the same as in the Solow Model. The savings rate and the depreciation rate are assumed constant and there is no population growth (Jones & Vollrath, 2013, p.217):

$$\Delta K = sY - \Theta K$$

We can get the dynamic capital-labor ratio from the equations above:

$$k=sAk - (n+\Theta) k$$

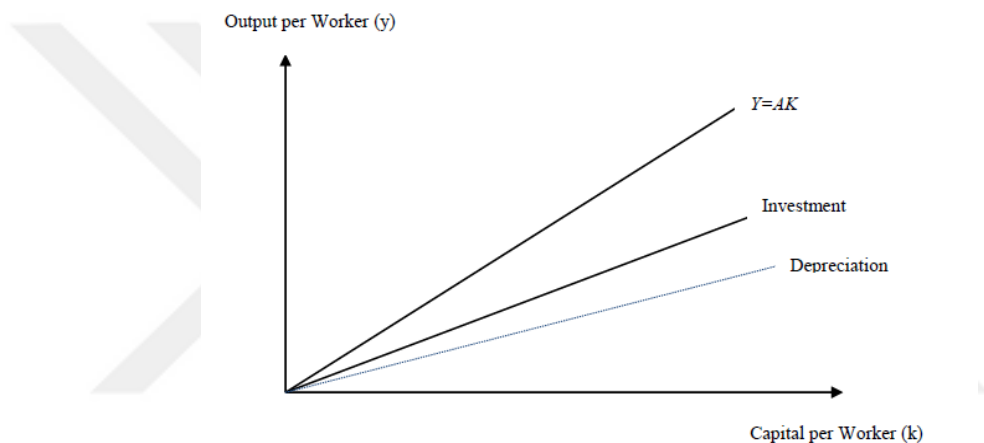
Dividing by k and taking derivatives of the production function, we can obtain the function of the growth rate of capital per worker since the output is a linear function of capital. The growth rate of output is equal to the growth rate of capital. So, the growth rate of per capita income would be as follows (Barro & Sala-i Martin, 2004, p.64):

$$y=sA - (n+\Theta)$$

The growth rate of per capita income rises in the same direction as the savings rate and technology, declines with the depreciation rate and the population growth rate. As long as the savings rate exceeds the depreciation rate and the population growth rate ($sA > n + \Theta$), the per capita income of the economy will expand

continuously. This increase in per capita income is achieved without technological change. We see that these simple mathematical explanations show a critical result of the AK model: Since we take A , n , Θ as fixed, the growth rate of the economy is an increasing function of the investment rate. As long as the output elasticity of capital equals 1, the transition dynamics in the growth process will never end. In this way, the AK model generates sustainable growth endogenously (Jones & Vollrath, 2013, p.216-219; Barro & Sala-i Martin, 2004, p.64-65).

Figure 1.3. The AK Model Growth Dynamics



Source: Greenhalgh & Rogers, (2010)

Figure 1.3. illustrates the growth dynamics in the AK model. The horizontal axis measures capital per worker, and the vertical axis measures output per worker. Production function ($Y=AK$) is a straight line as a linear function of capital stock reflecting the constant marginal product of capital. The gross investment is also a straight line since individuals save their income at a constant rate. These two straight lines are the most essential properties of the AK model and reflect its difference from the Solow model. The depreciation curve represents a fixed rate and is the same as in the Solow model. The distance between the gross investment curve and the depreciation curve represents the net investment with a positive value as long as $sA > n + \Theta$. If an economy saves sufficiently, the investment line would be above the depreciation line. The capital accumulation remains continuous, and the economy produces long-run growth in per capita income (Greenhalgh & Rogers, 2010, p.226-227).

The AK model stresses the relationship between policies and economic growth. Policies that affect the productivity and consumption-saving patterns of individuals may change the long run rate of economic growth. The model predicts divergence rather than convergence among countries since technology, the savings rates, the policies, and the initial capital stock of countries vary (Barro & Sala-i Martin, 2004, p.65). In analyzing growth, the AK model is a general approach suitable for both developed countries with sufficient capital accumulation and less-developed countries far behind them (Aghion & Howitt, 2009, p.13-14).

1.3.3. Romer Model (1986), Knowledge Accumulation

Paul Romer aimed to model technological change by emphasizing externalities. The source of long-run growth is rooted in the accumulation of knowledge created by forward-looking and profit-maximizing agents within the economy. Romer's model moves away from the usual assumption of diminishing returns to conclude that an unceasing growth through knowledge accumulation is possible. Knowledge can grow without limitations and spread throughout the economy via externalities. There is no optimal situation in which knowledge production comes to an end in the economy. Knowledge is assumed to be a production factor as an intangible capital good.

Romer proposes a growth model that includes a fully specified competitive equilibrium by combining three critical elements: externalities, increasing returns in the production of output, and diminishing returns in the production of new knowledge. The model asserts that it is possible to reach a competitive equilibrium despite the assumption of economy-wide increasing returns to knowledge. Likewise, the property of diminishing returns in the production of knowledge is crucial to ensure that global output production does not grow infinitely (Romer, 1986, p.1003-1004).

By adopting Arrow's approach, Romer recognizes that knowledge creation was a by-product of investment. As firms invest and accumulate more capital, they become more productive by increasing their experience. The impact of the

experience on productivity is named *learning by investing* in Romer's case (Barro & Sala-i Martin, 2004, p.213).

Since new knowledge cannot be kept private and patented effectively, all agents in the economy can use it without preventing the use of others. This is the source of knowledge spillovers and externalities in the economy (Romer, 1986, p.1015). In this regard, the critical point is that individual firms face diminishing returns when investing in knowledge. However, considering the whole economy, knowledge positively affects other firms' production, increasing their marginal product. That is why firms cannot control the increasing returns they generate and need to act competitively.

The considerations mentioned above imply that externalities will create a feasible growth rate for knowledge and a monotonically increasing growth rate for global output due to diminishing returns to knowledge production (Romer, 1986, p.1005). The model signifies very significant implications. First, the competitive growth rate is under the socially optimal growth rate due to the knowledge externalities. Firms may cause less growth rate than the optimum by investing less than expected. Second, economic policies can have permanent effects on growth. The last and most important, large economies can exhibit faster growth than smaller ones since they have more capital (Greenhalgh & Rogers, 2010, p.227-228).

1.3.4. Lucas Model (1988), Human Capital Accumulation

Lucas developed an alternative endogenous growth model in which accumulating human capital is the critical factor to generate sustainable economic growth. He argues that human capital not only raises the quality of the labor force but also increases the productivity of all production factors. The structure of his model is identical to Romer's knowledge accumulation model, but he claims differently that technology and knowledge diffuse across the economy through human capital. Rather than physical capital, the human capital assets of countries are responsible for the differences in their growth rate and per capita income (Acemoğlu, 2009, p.399).

Human capital accumulates at a rate proportional to existing human capital and represents knowledge and skills embodied in the workforce. Since it is considered an incremental value, workers acquire human capital through learning by doing or education. They allocate their time to current production (denoted as u) or skill acquisition (denoted as $1-u$). The latter is considered an initiative that will increase the future productivity of both individuals and the economy (Aghion & Howitt, 2009, p.293). If a constant rate of human capital is devoted to skill acquisition or education ($1-u$), human capital will rise steadily at a constant rate. As long as this accumulated human capital can be transferred between generations, the accumulation process will continue. The competitive economic environment ensures long-term economic growth by allowing efficient time allocation between production and education (Greenhalgh & Rogers, 2010, p230).

As the bearer of knowledge, human capital externalities are an essential component of the Lucas model. Individuals use knowledge in production and spread it to the whole economy by creating externalities. The increasing returns in the whole economy stem from these externalities. That is why human capital is a valuable asset not only for the firm that employs workers but for the whole economy, improving the efficiency of other firms (Aghion & Howitt, 2009, p.287).

1.3.5. Romer (1990), Product Variety Model

Romer (1990) made his fundamental contribution to endogenous growth theory by developing a product variety model in which new, but not necessarily improved, varieties of products generated overall economic productivity growth (Aghion & Howitt, 2009, p.69). He incorporated research and development activities and imperfect competition into growth theory. In Romer's model, technological change and knowledge arise from investment decisions and research and development activities made by profit-maximizing firms to accumulate an expanding variety of specialized intermediate products. These attempts are ultimately rewarded by some form of monopoly power establishing a competitive advantage for innovative firms and individuals (Barro & Sala-i Martin, 2004, p.20).

According to Romer, technological knowledge and ideas exhibit different characteristics than conventional economic goods. While most economic goods are rivalrous and excludable, they must be produced whenever consumed and can be consumed only by a single person. Ideas and knowledge are considered as a nonrival and partially excludable good. They need to be produced only once and are possibly consumed by many repeatedly. Nonrivalry means that anyone who knows that idea can take advantage of it, once an idea is created. Excludability indicates that the owner of an idea can hinder other people from using the idea. Besides, excludability is a function of both the legal system and the technological features of the idea (Romer, 1990, p.74-75).

The economics of ideas is closely related to increasing returns and imperfect competition. Each newly produced idea and design of a product has zero marginal cost and a fixed sunk cost, which is also described as research cost. For this reason, firms endeavor to produce innovative products as long as they can charge a price higher than the marginal cost (Jones & Vollrath, 2013, p.85). There is no payment to cover this sunk cost in competitive markets. The way to compensate for new ideas in general equilibrium is to take advantage of exclusive rights provided by the patent system that gives the owner of design the right to charge a price higher than the marginal cost. The profits and the monopoly power of firms obtained from new products prevail for a certain period, not forever (Aghion & Howitt, 2009, p.69).

Since advanced economies often produce technological knowledge, Romer's model is designed to understand how the advanced countries achieved sustained growth resulting from R&D activities. Romer constructed a disaggregated business sector model to examine the development of productivity in the economy. Romer's economy consists of three different sectors since output and ideas are produced in separate sectors: the research sector, the intermediate-good sector, and the final-good sector. The research sector is where new ideas and designs that will turn into capital goods are produced, and anyone who will contribute to the discovery of new capital goods can take part in it. The inputs of this sector are human capital and the existing stock of knowledge. When a new idea or design is discovered, the inventor receives a patent from the government for the exclusive right to produce new capital goods.

Then, the inventors sell the patent right to a firm that operates in the intermediate-goods sector. The intermediate-good sector firms manufacture capital goods using the designs and one unit of raw material that will turn into one capital good and sell the capital good to the final-good sector. The aggregate production function of the intermediate-good sector exhibits increasing returns thanks to the newly produced ideas and designs. As a result of their patent rights, they can set a higher sales price than the marginal cost. The profits earned by these firms are transferred to those who invent a new idea or design. Capital goods produced by the intermediate-goods sector represent the knowledge and technology in the economy. The final-goods sector consists of perfectly competitive firms that combine labor and capital to produce homogenous goods. Firms in this sector need to calculate how much labor and capital goods they will use in the production process, considering the profit maximization problem. This model is called monopolistic competition, and there is no economic profit in this model. The inputs of production receive all profits. Labor input in the final-goods sector receives a wage in return for its marginal product. Researchers gain a wage based on the value of the designs they discover. Capital earns a rent less than its marginal product. The remaining profit compensates for new ideas (Jones & Vollrath, 2013, p.98-119).

Romer also asserts that technological knowledge can be measured as a list of blueprints, each one defining how to produce a new product, how to reduce cost, or how to increase quality (Acemoglu, 2009, p.413). R&D activities also produce knowledge that is not embodied in the blueprints of the new product and can not be protected by the patent system. Other firms can access this disembodied knowledge, thereby reduces their R&D costs over time. Knowledge and ideas are subject to spillover effect resulting from this incomplete excludability and can be accumulated in the economy without bound (Romer,1990, p.74-75).

The most significant conclusions of Romers's model are as follows: First, the primary source of the growth is the accumulation of partially excludable and nonrival intermediate capital goods. Second, for having a long-term sustainable growth rate, firms and individuals should continue to generate new ideas and products that prevent the existing capital stock from running into diminishing returns. Third, the

stock of human capital devoted to research and development, not the population size or population density, determines the rate of growth (Romer, 1990, p.74-99). Lastly, it is crucial that the amount of profit obtained through a patent right and to what extent this profit will return to the research sector (Jones & Vollrath, 2013, p.117-119).

1.3.6. Grossman and Helpman Model (1991), Quality Ladders

Grossman and Helpman developed a different version of R&D driven, an innovation-based growth model that focuses on the quality improvements of existing consumer goods. The model argues that sustainable economic growth is possible with vertical innovations that increase the quality of existing products. Each improvement follows a stochastic progression creating a leap in the quality of existing products. The *quality ladder* approach assumes that each product can be developed unlimited times. However, the innovation process at the aggregate level is smoother and more stable than a single product. So, the index of consumer goods grows at a constant and steady rate (Grossman & Helpman, 1991, p.43-44).

Entrepreneurs and firms are free to compete for the following generation product. They search and realize opportunities in their industry, focusing their research activities on developing a qualified and a state-of-the-art version of an existing product available on the market (Grossman & Helpman, 1997, p.84-85). Each industry has a unique quality leader that stands one step ahead of the competitors due to the assumption of the model on production technology and the nature of intellectual property rights (Grossman & Helpman, 1991, p.-47). The competitors research to become the industry leader for a certain period and wish to gain positive profit under imperfect competition. However, they are aware that their innovations eventually will be replaced by new products in the future, making their product outdated (Grossman & Helpman, 1997, p.84-109).

Thanks to knowledge spillovers, which work slightly different from previous models, potential entrants can learn about the state of knowledge of existing products to perform their research efforts. These efforts contribute to a pool of knowledge and

thereby facilitate subsequent innovations. Both entrepreneurs and competitors, who are looking for a more improved version of a product, can work on the attributes of a newly developed product. Hence, every successfully developed product is not only the outcome of the work of a particular researcher or innovator but also the result of public knowledge that stems from technology spillovers (Grossman & Helpman, 1997, p.84-85). On the other hand, due to the oligopolist price competition, the leading firm does not invest in resources to develop its own product without gaining a cost advantage. To put it differently, the leading firm would transfer its resources to product developments in another market where it plans to become the market leader instead of expanding its own market (Grossman & Helpman, 1991, p.46-47).

A growing economy constantly needs new inventions and technologies. For this reason, the size of the research base is of substantial importance. Economic growth will be faster if the resources allocated to R&D activities are high enough. Sustainable growth is possible as long as R&D investments of innovators remain viable and profitable and the average quality of industrial products on the market continues to rise. Eventually, the economy will reach equilibrium in a steady state in which the growth is characterized by an aggregate rate of innovation (Grossman & Helpman, 1991, p.60).

1.3.7. Aghion and Howitt Model (1992), Creative Destruction

Joseph Alois Schumpeter put forward the idea of innovation as a means for creative destruction within the field of entrepreneurship in the late 1930s and early 1940s. Aghion and Howitt adopted this approach within the framework of the endogenous growth theory and formulated a growth model based on Schumpeter's creative destruction theory. Aghion and Howitt's model is very close to Grossman and Helpman (1991) but focuses on quality-improving innovations that increase the productivity of intermediate goods, rendering old products obsolete within a process of creative destruction (Aghion & Howitt, 2009, p.15-16). Vertical innovations of intermediate goods made by the competitive research sector form the basis of the model by speeding up the creative destruction process and are considered the primary source of long-term sustainable economic growth. The growth rate is

directly proportional to the economy-wide amount of research activities and skilled workforce. Since the model assumes that the amount of research in any period depends on the expected amount of research in the next period, the equilibrium in such an economy will be determined through a forward-looking equation (Aghion & Howitt, 1992, p.323-326).

The model predicts a stochastic but balanced growth of output. Technological advances follow a random sequence and make the arrival of the next innovation uncertain due to the very nature of the innovation (Aghion & Howitt, 1992, p.324-332). While the length between two successive innovations is stochastic, the relationship between research activities in these two periods can be modeled deterministically. The deterministic relationship of two successive innovation periods is formed by two critical factors: the creative destruction process and the wages of skilled labor. The feature of creative destruction and obsolescence implies an inverse relationship between current and future research. Therefore, the value of innovation depends adversely on the arrival of the next innovation. A short time interval between two consecutive innovations and an increase in expected innovation for the next period discourages firms from continuing research efforts since it decreases potential profit. In addition to this, higher demand for skilled labor for the next period increases real wages of labor and thus reduces the monopoly rents. This dynamic relationship between two research periods defines a static equilibrium that keeps the distribution of labor between research and production unchanged over time (Aghion & Howitt, 1992, p.324).

Aghion and Howitt present a general equilibrium model, including a perfectly competitive final-good sector and an intermediate-good sector having a monopoly power (Aghion & Howitt, 2009, p.85-86). Individuals are heterogeneously endowed with specialized, skilled, or unskilled abilities and a one-unit flow of labor. The skilled labors are employed in the research sector and intermediate-goods sector, unskilled labor work in the consumption good sector, and specialized labor work only in the research sector (Aghion & Howitt, 1992, p.327). The consumption goods are produced by competitive firms that employ intermediate goods and unskilled labor. Firms with monopoly power manufacture intermediate goods using skilled

labor. Final goods that are not used in the production of intermediate goods are available for consumption and research activities, and constitute the gross domestic product of the economy (Aghion & Howitt, 2009, p.85-86).

The intertemporal spillover effect plays a vital role in this model. Technological knowledge is shaped by the stock of innovative studies carried out by current and past innovative firms and the attempts of prospective innovative firms. Due to the spillover effect, the knowledge of past innovations is available to everybody in the economy and provides positive externalities for future innovation activities (Aghion & Howitt, 2009, p.16). Prospective innovators build their works upon the basis of the current innovator without compensating it. As a consequence of creative destruction, the innovation process generates losers and winners. However, the entire economy will benefit from the creative destruction process and generate long-run growth.

1.3.8. Rivera-Batiz and Romer Model (1991), Foreign Trade, Integration and Openness

Rivera-Batiz and Romer developed an endogenous growth model that links international trade and long-run economic growth. They studied economic integration as the source of technological change considering two fundamental sectors in the economy. The research and development sector produces new ideas and makes continuous growth possible, and the manufacturing sector produces consumer goods and specialized intermediate goods using new ideas (Rivera-Batiz & Romer, 1991, p.1).

The model argues that the gains from international trade can arise in two ways, both from differences in competitive advantage and from economy-wide increasing returns. Economic integration promotes the exploitation of increasing returns in the research and development sector worldwide. If an economy eliminates the barriers to international trade, it will free the flow of goods and ideas across countries. Through closer economic integration and international trade, firms operating in the same sector but different countries can have increasing returns

arising from knowledge spillovers. Another way of gaining increasing returns due to economic integration can be achieved by permitting the flow of special intermediate inputs produced by foreign firms competing as monopolists in a different country (Rivera-Batiz & Romer, 1991, p.1-6).

The degree of integration is determined by the trade of specialized intermediate goods, the flow of ideas through externalities, and investment by multinational corporations. The combined output of all firms in a sector will increase according to economic integration. In order to grasp the effect of trade on growth, the model considers integration only between similar countries and decomposes the effects of trade. The impacts of trade and openness on the long run economic growth occur in ways: the allocation effect, the integration effect, and the redundancy effect. The allocation effect links different sectors in the same country. When a country opens for trade, it reallocates resources toward the sector they have a comparative advantage. The allocation effect sometimes increases or sometimes decreases economic growth, depending on the sector-specific conditions and trade policies. If the trading partners have different technologies and endowments, the allocation effect of trade can be enormous. The integration effect links the same sectors in different countries and is mainly induced when a sector exhibits increasing returns. The production scale of firms and the worldwide output will be larger if the two national sectors are integrated. The redundancy effect only occurs in the research sector. Trade restrictions induce redundant research efforts in different countries. In the case of integration, the worldwide research output increases because of the competitive pressures induced by closer ties among countries. Integrated countries compete to invent new technologies and avoid reinventing the same technologies (Rivera-Batiz & Romer, 1991, p.1-3).

1.3.9. Segerstrom Model (1991), Imitation

Segerstrom presented a general equilibrium model with a steady-state equilibrium and constant economic growth rate. He used the framework of the product innovation model and expanded it by allowing firms to strive for imitative R&D activities. Firms determine the rate of innovation and imitation of the economy

endogenously. As firms invest in R&D and successfully develop innovative products, their profits attract other firms' attention, encourage imitative efforts, and accelerate economic growth and product development.

All firms can participate in innovative and imitative R&D races. While new products are discovered periodically by innovative firms, other firms devote imitating efforts to discover the state-of-the-art quality of these products. In the end, every product becomes obsolete, and its profits can not last forever (Segerstrom, 1991, p.1-29).

The model predicts that the steady-state equilibrium characterizes aggregate innovative and imitative R&D expenditures in each industry. Some industries attract innovative ideas, while some industries attract imitative efforts. This steady-state equilibrium has some basic properties: Due to profitability, in industries with a single quality leader, other firms engage in imitative activities, and in industries with two quality leaders, other firms engage in innovative activities. Quality leader firms do not undertake innovative activities. There is not any industry that has more than two quality leaders. These steady-state properties are consistent with the maximization approach of all economic agents. Since the number of leaders and followers in each sector determines which efforts, innovative or imitative, will dominate the sector, a continuous cycle between innovative and imitative efforts shapes the industries. Thereby a constant equilibrium is achieved. The economy always maintains equilibrium by innovating in some industries and by imitating in some industries (Segerstrom, 1991, p.1-13).

1.3.10. Blomstrom and Wang Model (1992), Foreign Direct Investment

The fundamental motivation for developing countries to attract foreign direct investment is to establish a foundation for local innovation capacity and obtain advanced technologies through technology transfer. Blomstrom and Wang developed a growth model in which international technology transfer takes place endogenously due to the interaction between a multinational corporation (MNC) subsidiary and the host country firms. The model clearly states that the MNC and the host country firm

must take into account the cost of technology transfers to MNC and the cost of learning to the domestic firm when they make a strategic investment decision.

MNC's are assumed to have superior technological knowledge and are considered the key actors in the diffusion and application of modern technologies. The host countries' production efficiency and growth potential are directly proportional to foreign investments from MNC's. Competing host country firms become more efficient with the technology spillovers created by foreign direct investments (Blomstrom & Wang, 1992, p.1-2).

Blomstrom and Wang consider two firms in their model, a subsidiary of MNC and a host country firm. They come together to produce a differentiated product for the market of the host country firm. The subsidiary, host country firm and other domestic firms differ in their accessibility to production technology flowing through foreign investments. The subsidiary firm has access to the R&D activities made by the parent company of MNC. The host country firm learns from the subsidiary firm. The level of technology transfer via foreign direct investments is also directly proportional to the learning investments of the firms. Although learning is costly and time-consuming, the learning effect makes technology transfer cheaper, especially when relatively old technologies are transferred over the latest technologies (Blomstrom & Wang, 1992, p.3-5).

An important suggestion of the model is that government incentives are needed and vital for domestic firms in host countries to invest in learning. Governments of host countries should focus on supporting domestic firms in their efforts to learn from foreign companies since the success of technology transfer depends mainly on the efforts of host firms. It is also expected that the host country will be confident of obtaining sufficient or substantial benefits from multinational corporation investments (Blomstrom & Wang, 1992, p.19-21).

1.4. The Implications of Growth Theories

This part briefly summarizes the growth models discussed in this section. The subtitles contain the model's approach to technological change, the source of long-term growth, and policy implications.

The Solow Model (1956)

The Solow model places capital accumulation at the forefront of short-run growth by accepting exogenous technological change as fixed in the upcoming period. At this stage, what distinguishes countries economically is the amount of capital per worker. However, capital is subject to the law of diminishing returns. Its profit will come to a halt at a certain point called steady-state. In this transition period, population, savings, and depreciation strongly influence the short run growth rate. They all appear to generate different growth rates across countries. The recovery of capital and labor productivity from diminishing returns depends on technological change, which is considered the key to the long run economic growth. Technological change arises from exogenous sources other than the economic domain. Therefore, it does not allow any economic policy for sustainable long-term growth. Saving, investment decisions, and government policies become insignificant.

Moreover, as technological changes spread globally, any cross-country difference in technological knowledge or production factors loses its importance in the long run. This important feature of technology creates an optimistic view of the long-term convergence in the per capita income of rich and poor economies, strongly expressing those poorer countries will grow faster and eventually catch up to richer countries regardless of their initial conditions. This pessimistic implication prevents governments from any policy implementation for long-term sustainable economic growth.

The Ramsey-Cass-Koopmans Model (1965)

The Ramsey-Cass-Koopmans model acknowledges technology as an exogenous factor and a vital determinant of the long-term equilibrium. However, in the short term, the model presents a unique approach by analyzing the growth

phenomenon on its micro basis. The individual's preferences dynamically determine the consumption-savings balance of the economy due to efforts to maximize lifetime benefits. Since capital accumulation depends mainly on the decisions of individuals, decentralized economic decisions are of great importance in short term growth. As a policy recommendation, this model state that governments can achieve short-run growth by guiding saving choices. In the long run, the growth rate of economies equates to the rate of technological change that is a given factor for economies.

The AK Model

The AK model argues that long-term sustainable growth is possible with the internal dynamics of economies. Firms can obtain technical change through factor accumulation or learning by doing without the need for external technological development. The economy will achieve long-term growth by producing technical knowledge with its internal dynamics. Technical knowledge diffuses to the rest of the economy via externalities, and gains a public good character. In this way, it creates a counterbalance against the tendency of diminishing returns by allowing capital to earn fixed marginal returns. Increasing savings and investments will emerge as the main source of long-term growth. The model supports policy recommendations to be offered to accelerate capital accumulation. As the mentioned internal dynamics differ, there will be a divergence between countries, not convergence, in the long run.

Romer Model (1986), Knowledge Accumulation

Romer adopts the AK-type growth approach, considering knowledge accumulation as the main source of long-term sustainable economic growth. Knowledge is an intangible capital acquired through learning by doing and can grow unlimitedly and used by all firms due to dynamic externalities at the aggregate level of the economy. Knowledge provides economy-wide increasing returns in the production of goods, but firm-based knowledge production is subject to diminishing returns. The combined effect of the private knowledge of firms and the economy's aggregate public stock of knowledge ensures a monotonically increasing long-term growth rate. Since economic growth is tied to firm-based dynamics, economic policies focusing on capital accumulation and knowledge accumulation will have

permanent effects in the long run. Developed economies with intense capital accumulation grow faster than less developed economies.

Lucas Model (1988), Human Capital Accumulation

This is another growth model based on factor accumulation, learning by doing, and externalities. Lucas regarded human capital accumulation as the primary driver of long-term sustainable growth. Technological knowledge embodied in human capital and disseminates across the economy with the help of externalities and plays an essential role in generating long-term growth. Human capital leads to cross-country differences in acquiring new technical knowledge and applying existing technologies. Countries with intense human capital will grow faster than countries that do not invest enough in human capital. For sustainable economic growth, the policies that support human capital accumulation should be implemented.

Romer (1990), Product Variety Model

Innovation and creativity are significant sources of technological change and increasing returns. Rather than externalities, the deliberate R&D activities of entrepreneurs and firms constitute the essence of the long run economic growth. The variety of intermediate goods used in the production of final consumption goods is the main indicator of innovation and technological change in an economy. The model vigorously emphasizes the need for monopoly power for profit-seeking firms and entrepreneurs to invest in innovation. The research cost of each newly produced intermediate goods should be protected by intellectual property rights to ensure the continuity of R&D activities. Human capital matters, not the labor force. The more human capital is devoted to research and development, the higher the economy's growth rate. Another important implication of the model is that free international trade will accelerate economic growth, as integration with larger markets encourages further research. Government subsidies should also be raised for R&D efforts to support and boost economic growth.

Grossman and Helpman Model (1991), Quality Ladders

Step by step improvements in the quality of existing products based on innovation, creativity, and R&D efforts are the source of long-term sustainable growth. An essential requirement for sustainable growth is that firms and entrepreneurs should participate in a race to achieve monopoly power for a certain period. It should be viable and profitable to develop existing products. In addition to deliberate R&D efforts, knowledge externalities also play a significant role in this model since developing a more advanced version of an existing product requires a stock of public knowledge about the attributes of that product. This model also established a multi-country equilibrium model by linking economic growth with foreign trade, predicting that countries can strengthen their innovation bases through technology transfer or increase innovation gains via expanding market size.

Aghion and Howitt Model (1992), Creative Destruction

The model draws attention to the fierce competition in improving the quality of existing products and assumes that it speeds up the process of creative destruction. Innovations made by the competitive research sector on intermediate goods are the primary source of long-term sustainable economic growth. Therefore, a large number of research efforts and a skilled workforce are required. The time interval between two innovation periods and the skilled labor costs will determine the balanced process of technological innovation since the monopoly profit is heavily related to these two ingredients. Externalities have substantial importance as potential innovators build their work on existing innovators' knowledge and technology. In creative destruction, continuous firm entry and exit into the economy will occur. However, long-term economic growth will ultimately be achieved as the fruit of this competition.

Rivera-Batiz and Romer Model (1991), Foreign Trade, Integration and Openness

The effect of market integration on economic growth was analyzed in terms of technological change. Countries both gain from foreign trade due to their

competitive advantages and exploit from international increasing returns via foreign trade. Therefore, foreign trade, integration, and openness can be considered to accelerate technological change and economic growth. Foreign trade allows countries to direct their resources to sectors where they are more technologically efficient and increases significantly the extent of the market for technology producing countries. Openness and economic integration facilitate the flows of knowledge, ideas and special technological products across countries, leading to an increase in the rate of growth globally. Openness and integration also prevent repetitive and unnecessary R&D efforts due to intense competition and trade links between economies.

Segerstrom Model (1991), Imitation

Firms' strong R&D race will ensure long-term sustainable economic growth through innovation and imitation. The model emphasizes the importance of imitation along with innovation since imitation promotes technology-driven economic growth. Firms can engage in innovation or imitation. The number of leader firms and the number of follower firms in each industry determines whether firms will focus on imitation or innovation. A perpetual transition takes place between innovative and imitative efforts in each industry, and in this way, stable, balanced long-term growth can be achieved. Government subsidies can change this steady-state equilibrium. For the long run economic growth, an economy should increase the steady-state intensity of innovative efforts. Since imitation efforts increase the steady-state intensity of innovation, government subsidies to boost imitation efforts will be beneficial to economic growth.

Blomstrom and Wang Model (1989), Foreign Direct Investment

Another way to increase innovation capacity and technological knowledge is by transferring it through foreign direct investments. Technology transfer will make a significant contribution to the long run growth, competitiveness, and export performance of the host country only in exchange for the cost of learning. This strategic investment decision of the host country firm also provides positive learning externalities on the other domestic firms, improving their production efficiency. The

need for incentives to learn is a requirement in host countries because the success of technology transfer depends largely on the host country firms. Governments should focus on supporting their domestic firms in learning from foreigners.

1.5. Literature Review of the Empirical Studies

A significant body of empirical studies examines the impact of innovative activities on economic growth and export. Especially following the emergence of theoretical models that involve endogenous technological change created by the efforts of forward-looking firms, the studies attempting to explore empirical evidence for the validity of these theories have accelerated. As explained in the previous section, a firm can achieve its technological knowledge in many different ways. The most extensive and preferred way of obtaining technological knowledge is through deliberate research and development efforts. Therefore, R&D expenditure has been acknowledged as the main indicator of innovative activities in almost all empirical studies. Accordingly, this section presents the studies that consider R&D expenditure as an explanatory variable and examine its impact on economic growth and export.

A quick review of the literature shows that the number of disaggregated studies that specifically examine the R&D performance of manufacturing industries is quite limited. The empirical studies on the subject focus mainly on analyzing the impact of R&D expenditures on economic growth and export for a country or a group of countries at the aggregate level. In addition, a new aspect of the literature on the subject, firm-based micro-level studies, seems to be developing. These studies, which aim to measure the impact of R&D expenditures on firms' growth and export performance, have attracted particular attention in recent years.

After reviewing a large body of country-based and sector-based empirical literature, this section briefly introduces prominent empirical studies and focuses primarily on recent ones. The studies fall into three categories: aggregated studies covering single or multiple countries, disaggregated studies focusing on manufacturing industries, and those analyzing the impact of R&D expenditure on export. The literature will be presented according to this categorization. The

empirical literature of this thesis will not include firm-based inquiries since this study aims to evaluate the R&D performance of the manufacturing industry sectors.

1.5.1. Empirical Studies on the Relationship Between R&D Expenditure and Economic Growth

Empirical studies on the relationship between R&D and economic growth have predominantly focused on aggregated data of a single country or a group of countries. Solow (1957) set up one of the first empirical studies and considered a neoclassical production function for the U.S. economy. Solow's purpose was to apply an assessment of the sources of economic growth based on the data from the United States economy for the period 1909-1946. The study revealed a striking outcome that economic growth was driven by another component with a much broader impact than usual production factors such as capital accumulation and labor. This component is referred to as *the Solow residual*, representing the increase in production achieved by technological change. 87.5% increase in per capita production was due to technological development. The findings of Solow's empirical work emphasized the importance of technological development as the main driver of economic growth not only in theory but also in practice. Solow could not find an answer about how this technological change came about, and he accepted technology as an external factor. After the study, economists turned their attention to the source of technological knowledge and how it changes and differs over time and across nations.

An extensive, multi-country study testing the impact of R&D spending on growth was conducted by Lichtenberg (1992). He focused on investment in research and development rather than tangible assets such as equipment and machines in measuring productivity growth. The relationship between R&D investment and economic growth was tested by employing annual R&D and GNP data of 74 countries from the years 1964-1989 with the nonlinear least-squares estimation method. The variables that Lichtenberg used in his study involve the ratios of privately-funded R&D investment and government-funded R&D investment to GNP. The results of the study revealed that the private sector R&D expenditures had a

positive and significant effect on growth, and this effect was unexpectedly large. Furthermore, government R&D expenditures had a significantly lower impact on growth. However, government R&D spending may have unmeasured benefits at least in areas such as health and national security where government R&D spending is related.

Following Lichtenberg, cross-country studies covering different periods have been implemented. One of them belongs to Freire-Seren (2000). By adopting Romer's product variety model, Freire-Seren developed an empirical model in which new and differentiated products form the core of the economy. R&D spending was assumed to expand product variety. To provide empirical evidence for this theoretical approach, Freire-Seren examined the data of 21 OECD countries between the years 1965-1990 with a panel data analysis method and identified a strong positive relationship between R&D expenditure and the growth of GDP. The estimation coefficient shows that a 1% increase in the aggregate R&D expenditure raises the real GDP by 0.08%. Another cross-country study covering a more recent period was conducted by Gülmez and Yardımcıoğulları (2012). Their work included 21 OECD countries over 1990-2010 using the panel data analysis and FMOLS and DOLS estimators. According to estimation results, the elasticity of per capita R&D expenditures was calculated as 0.77%, implying a significant contribution to per capita income growth. The per capita R&D expenditure elasticity was calculated as 0.64% for Turkey. Besides, a bilateral causality relationship was identified between per capita R&D expenditures and growth in the long run. A large sample of countries with different economic development levels was tested in another study. Inekwe (2014) focused on 66 developing economies and used the dynamic system GMM regression method to measure the relationship between R&D and growth over 2000-2009. All of the 66 countries were classified as lower-middle-income economies (LMIE) and upper-middle-income economies (UMIE) in line with the income level classification of the World Bank. The findings show that the positive effect of R&D expenditure applies to the upper-middle-income group, while it is found insignificant for the lower-middle-income group.

Bayraktutan and Kethüdaoglu (2019) tested the impact of R&D spending by disaggregating it into private, public, and higher education. For this purpose, they used annual data of 29 OECD member countries from 1996-2015 and evaluated the impact of R&D expenditures on economic growth using panel data analysis. The study shows that aggregate R&D expenditures positively and strongly impact economic growth. 1% increase in the private sector R&D intensity increases the growth rate by 2.61%, 1% increase in the government sector R&D intensity increases the growth rate by 1.84%, and 1% increase in the higher education R&D intensity increases the growth rate by 5.83%. An inquiry that extended the explanatory variables was conducted by Özkan and Bayar (2019) by adding ICT products export, the number of patents, and R&D expenditure. The focus was 16 growing economies and the 2000-2015 period, and panel data analysis and panel DOLS estimator were used. The findings of the study indicate that all these innovative variables have a positive effect on economic growth in the long run. A one-unit increase in R&D expenditure contributes to a per capita GDP of 14 units and a one-unit increase in the number of patents contributes to a per capita GDP of 1.2 units.

To add two more examples of cross-country studies, Sarıdoğan (2019) intended to measure the impact of R&D expenditure on economic growth, focusing on 28 EU countries over the period 1998-2017 using panel data analysis. According to the analysis results, there is a positive and significant relationship between R&D expenditures and economic growth. 1% increase in per capita R&D expenditure leads to a 0.18% increase in real GDP. Türkmen et al. (2019) focused on 20 OECD countries to investigate the relationship between economic growth and R&D expenditures in the period 1991-2016 with the help of dynamic panel data analysis. The outcome of the analysis proves a positive and statistically significant relationship between R&D expenditures and growth.

We should also mention a different study that adds foreign R&D stock as the source of knowledge and technology acquisition. Coe and Helpman (1993) discussed R&D from two different sources and argued that the productivity of a country depends on both its own R&D stock and the R&D stock of its foreign partners. Then, they tested the impact of both domestic and foreign R&D capital stocks on total

factor productivity for 22 countries including 21 OECD countries and Israel during the period 1970-1990 using the panel data analysis method. Cumulative R&D expenditures were used to proxy domestic and foreign knowledge stocks. The results showed that domestic and foreign R&D capital stocks strongly affected the total factor productivity of a country. While the foreign R&D stock is as effective as the domestic R&D stock in smaller countries, the domestic R&D stock is much more important in larger countries. Due to the strong impact of foreign R&D investments, open economies earn greater productivity benefits than R&D investments via their trade partners.

Some of the empirical studies targeted a particular group of countries regionally. Yanyun and Mingqian (2004) empirically studied the innovative efforts of ASEAN + 3 countries, which prioritize regional economic cooperation, competitiveness, and industrialization. The long run relationship between economic growth and R&D expenditures for eight economies was investigated over the time interval from 1994 to 2003 using panel data analysis. The study found an interactive relationship between R&D expenditure and economic growth. The R&D expenditures of each country mainly depend on their development level. In addition to this, some factors such as the depth of the credit market and technological cooperation are also influential. Bujari and Martinez (2016) focused on 12 Latin American economies to investigate the impact of technological innovation on economic growth during the period 1996-2008. They estimated the model with the help of dynamic panel data analysis and the GMM system method. R&D expenditures, number of patents, and high technology exports were taken as indicators of innovative activities. The results show that R&D investments and all other innovative explanatory variables significantly impacted GDP per capita.

Kim (2011) targeted a developing country in Asia. The impact of the R&D stock of South Korea on its economic growth performance for the period between 1976 and 2009 was analyzed using time series analysis. Based on the empirical results, Kim found that R&D stock accounts for 35% of South Korea's economic growth for the mentioned period, while capital and labor account for 65% of the

growth. The 35% contribution of total R&D expenditure came from the public and private sectors with 16% and 19%, respectively.

There are also empirical studies that address Turkey and other countries together. Erdemli and Çelik (2017) investigated the link between R&D spending and economic growth for G7 countries and Turkey with panel data from 1996-2014. The results indicated that R&D spending positively affects economic growth. According to the FMOLS estimator coefficient, a 1% increase in R & D expenditures provides an increase of 1.168% in GDP. Sökmen and Aşcı (2017) tried to measure the efficiency of R&D spending, focusing on BRICS-T (Brasil, Russia, India, China, South Africa, and Turkey) countries. Panel data analysis was performed for 1999-2015 by obtaining the data from the World Bank and OECD databases. The study found a long-term relationship between R&D spending and GDP growth rates of BRICS-T economies. The causality relationship from GDP to R&D for Russia and South Africa, and from R&D to GDP for Brazil was identified.

The following part consists of the empirical studies that examine the performance of aggregate R&D expenditure of Turkey. There are many studies in this field in the literature, but only some are included in this section since these studies do not differ much in terms of method, period, etc. Taban and Şengür (2013) examined whether R&D expenditure and full-time equivalent R&D employees provide a positive contribution to the economy as a result of increasing returns, as stated in endogenous growth models. The relationship was estimated with the annual data between 1990 and 2012 using Johansen cointegration and vector error correction methods. The findings indicate that while R&D expenditure affects economic growth positively only in the long run, the number of full-time equivalent R&D employees positively affects economic growth in the long and short run. With a different perspective, Baykul (2018) conducted an empirical study based on 12 regions of Turkey (in line with the NUTS statistical region classification) and analyzed the effect of regional R&D expenditure and R&D employment on regional economic growth over the period 2010-2014 using panel data analysis. The results indicate that R&D expenditure and R&D employment provide a positive and statistically significant contribution to regional economic growth. Uçak et al. (2018) investigated

the relationship between R&D expenditure and GDP over 1990-2016 in Turkey using the ARDL boundary test. The effect of the R&D variable on GDP was found to be positive and significant in the long run. The R&D/GDP ratio consistently explains the GDP function. 1% increase in the ratio of R&D/GDP leads to a 5.92% increase in GDP. İğdeli (2019) studied the impact of R&D expenditure and education expenditures on economic growth for Turkey over the period 1990-2016 using the ARDL boundary test. The ratio of education expenditure to GDP and R&D expenditure to GDP were used as explanatory variables. The study found that R&D expenditure and education expenditure positively affect economic growth in the long run. A causality relationship from R&D to GDP was also found. Genç and Tandoğan (2020) analyzed the impact of R&D expenditure on economic growth using annual data between 1990 and 2017 in Turkey. A Residual-Based cointegration test with the Fourier Approximation method was applied. The findings of the study that the two variables are cointegrated and 1% increase in R&D expenditure increases economic growth by 0.5%. A two-sided causality relationship between R&D and GDP was also identified.

1.5.2. Review of Empirical Studies on the Relationship Between R&D Expenditure and Economic Growth for Manufacturing Industry

Zvi Griliches (1967; 1980) conducted pioneering studies in measuring the impact of technology and innovation on total factor productivity and economic growth. His fundamental contributions came in the field of econometrics. Griliches tried to explain the unmeasured "residual" by adding the variable of knowledge or technology to the traditional production function. He implemented a series of works on the U.S. manufacturing industries. Before that, his focus was to measure the technical change in agriculture, by extending this work, in 1967, Griliches conducted a detailed analysis on U.S. manufacturing two-digit industries using the cross-section data obtained from *the 1958 Census of Manufactures*. But, he analyzed mainly the quality of labor and economies of scale due to limited data in scope and quality. He described this paper as an attempt to find the source of growth. It is a preliminary but not a complete or definitive study. A different set of data was needed to measure the

contribution of capital and R&D expenditure on growth. In 1980, Griliches aimed to investigate the productivity decline in the U.S. economy observed in the latest period. For his research, he chose the manufacturing industry as a field where the efficiency of R&D expenditure could be measured in the best way and used the data from thirty-nine U.S. manufacturing industries for the period 1959-1977. He defined his findings as clouded or ambiguous and stated that R&D expenditure had a negligible effect on the observed decline in productivity. He added that R&D expenditure had no significant effect between 1969 and 1977 when the data were split into two periods. Although the study tried to point out unexplained fluctuations in total factor productivity, some interpreted these results as the depletion of scientific opportunities (Griliches & Lichtenberg, 1984, p.465-466). Griliches and Lichtenberg (1984) conducted a new inquiry and attempted to solve the data and the methodology problems encountered in the previous works. The data covered the years 1959-1976 and included four-digit sectors of the American manufacturing industry. The results showed that R&D impact on productivity did not disappear. In all four sub-periods of 1959-1976, private R&D expenditure intensity was positive on TFP. The decline in productivity affected R&D-intensive industries to a lesser extent. Prior to Griliches and Lichtenberg (1984), Nadiri (1979) had addressed the issue of productivity decline in the U.S. economy and questioned which part of this slowdown can be attributed to the decline in R&D expenditure. His investigation was based on the impact of R&D expenditure on output growth in the U.S. manufacturing industry. The study, supported by the data covering 1958-1975, found a strong relationship between R&D stock and output growth in total durable and nondurable industries. It is particularly effective in the second year of the R&D investment. The study had inconclusive results on the effect of government-supported R&D spending. He added that these outcomes were insufficient and more research needed.

We should also include a more recent study covering a broader period for the U.S. manufacturing industry. Zachariadis (2002) used annual data from 1963-1988 to estimate the relationship between R&D intensity and productivity growth. Zachariadis opted for the manufacturing industry because the vast majority of R&D spending in the United States was in the manufacturing industry. It is also important

to approve the validity of R&D-based growth models. The prediction was conducted using three different equations: the effect of R&D intensity on patenting, patenting on technological progress, and technological progress on economic growth. The study estimated a positive impact for all three equations and found that R&D intensity positively impacts innovation, technological progress, and economic growth. Another important finding of the study is that aggregate R&D expenditure provides vital support to industry-level patenting by contributing more than each industry's R&D expenditure, implying strong spillovers across industries.

Griliches and Mairesse (1982) kept searching for the causes of productivity slowdown in recent years with a comparative study between the U.S. and France. The study predicts some possible reasons causing productivity slowdowns, such as R&D inefficiency, inadequate investment, and rising energy or raw material prices. Total factor productivity growth in the manufacturing industries at a two-digit level was compared. None of the reasons seemed to explain the productivity differences between the two countries. However, the study confirmed that R&D intensity could be responsible for small productivity differences during 1967-1978. The study recommended that comparative analysis be encouraged and pursued by others by highlighting the obvious and unresolved problems. Mohnen et al. (1984) conducted a similar comparative productivity analysis for the manufacturing industries of three major industrialized countries: The U.S., Japan, and Germany. Labor, energy, capital, and R&D inputs were used in a dynamic factor demand model covering 1965-1977. The study concluded that R&D needs a longer time than capital to contribute to the output. The average lag for R&D differs from country to country. Another comparative study worth mentioning was the work of Nadiri and Kim (1996). They compared the production structure of countries with different stages of development for a relatively different time interval. The study evaluated the U.S., Japanese, and Korean manufacturing industries for the 1974-1990 periods. In addition to physical and R&D capital, markups, scale returns, technical changes were used for forecasting. While R&D expenditure stood out with its significant contribution to growth for Japanese and American industries, a relatively more minor

contribution was identified for Korea by noting its rapidly increasing performance and not far from the other two.

Following the studies that concentrated on the leading countries in technology and industrialization, we come across more extended, multi-country studies in the literature. Perelman (1995) conducted an empirical study on eight manufacturing industries of eleven OECD countries to estimate productivity growth over the period 1970-1987 using the parametric and non-parametric frontier approach. The productivity growth was decomposed into two components, technological change, and efficiency change. The relationship between productivity growth and technological change was analyzed with a set of explanatory variables, including R&D expenditure. The results obtained from the estimation show that R&D spending creates a positive and significant impact on technological change and technological change is the leading source of productivity growth. Keller (1997) directed another study on the manufacturing industry of OECD countries for the period 1970-1991. In this study, he examined 13 manufacturing industry sectors of 8 countries by expanding the number of sectors. The study confirmed a relationship between R&D expenditure and productivity. The elasticity of total factor productivity to own-industry R&D was estimated between 7% and 17%. Outside-industry R&D investments contribute to productivity at a rate of one-fifth of own-industry R&D investments. Another study comparing the different sources of technology was conducted by Acharya and Keller (2007). They explored the differences in total factor productivity across countries regarding R&D expenditure and foreign technology spillover. The data was taken from 22 manufacturing industries in seventeen industrialized countries from 1973-2002. System General Method of Moments, Olley-Pakes, Olley-Pakes/Wooldridge estimators were employed for the prediction. The study found that R&D is an important determinant of productivity. A 10% increase in domestic R&D expenditure leads to an average 1.5% increase in productivity. Another important finding is that the impact of international technology transfer on productivity often outpaces that of domestic R&D expenditure.

Two more recent studies that sample OECD countries are as follows. Bojnec and Ferto (2011) aimed at investigating the impacts of R&D expenditure on bilateral

manufacturing trade in 18 OECD countries for the period 1995-2003 using panel data analysis. The research outcomes show that the R&D expenditure was found positively associated with manufacturing trade for exporting countries, but not for importing countries. The effect of R&D on sectoral trade varies depending on whether the sector is a net producer or a net consumer. On the other hand, R&D may improve manufacturing import specialization and help overcome exporting to long distances. Doyar (2020) investigated the impacts of R&D expenditure on the value-added of five manufacturing industry sub-sectors in 28 OECD countries for the period 1998-2015 using panel data analysis and FMOLS-DOLS estimators. The findings indicate that R&D expenditure mostly affects the value-added of the machinery and transport equipment sector. 1% increase in R&D in this sector affects positively the value-added of the machinery and transport equipment sector by 0.8%. The second place belongs to the medium and high-tech sectors. 1% increase in R&D in this sector affects positively the value-added of medium and high-tech sectors by 0.6%. 1% increase in R&D in chemicals and food-beverage-tobacco sub-sectors affects positively the value-added of both sectors by 0.4%. Only the textile and clothing sector is negatively affected by R&D expenditure. Except for the labor-intensive textile and clothing sectors, the other four sectors have compatible results with the literature.

A different study should be noted in terms of the concept it handles. Aydın (2018) examined the contribution of R&D expenditure to manufacturing value-added in the industry 4.0 processes. Nine leading economies benefiting from Industry 4.0 were selected as the sample, and the data of these countries for the period 1996-2015 were analyzed with the help of panel data analysis. The findings of the study tell us that R&D expenditure as a share of GDP has a significant impact on manufacturing value-added and these two variables have a two-sided causality relationship.

A comparative study of two Southern European countries, which are structurally different from the Northern and Central European countries and qualified as technology followers in the study, is also worth mentioning. Sterlacchini and Venturini (2014) applied a comparison between Italy and Spain concerning R&D and productivity in high-technology manufacturing. Using dynamic panel estimation

method, they examined the effects of R&D stock on total factor productivity in 12 manufacturing industries from 1980-2006. The study revealed that the Spanish manufacturing industry performed higher R&D flexibility than its Italian counterparts. The findings suggest that a 5% increase in R&D stock leads to an increase in the total factor productivity of R&D-based manufacturing industries by 1.15% for Spain and by 0,9% for Italy only after a sufficiently long period.

As stated, the disaggregated studies specific to the Turkish manufacturing industry are quite limited in the literature. In this part, we present the previous studies examining the impact of R&D expenditure carried out by the Turkish manufacturing industries on economic growth. Bozkurt (2007) tested the growth model of the Turkish manufacturing industry during the period 1992-2001 within the framework of endogenous growth theory. The relationship between the growth of sectoral added value, sectoral R&D expenditure, and sectoral technical personnel was examined through panel data analysis and the GMM system estimation method. The model investigated whether the manufacturing industry exhibits an AK-type growth trend. The critical result of the study was that the Turkish manufacturing industry did not exhibit an endogenous growth trend in this period in terms of the contributions of R&D expenditure and technical personnel. The industry's growth trend was mainly related to the cost of labor and inputs. Therefore, it exhibits a neoclassical growth trend, not an endogenous one. In another study, the manufacturing industry was examined according to the technology intensity of its sub-sectors. Avcı (2007) investigated the impact of the R&D expenditure of Turkish manufacturing industry sub-sectors on economic growth. In this thesis, panel data analysis was used by benefiting from the sectoral data for the period 1992 - 2001. The analysis was carried out on 21 sub-sectors by separating them into low-medium-high technology categories in accordance with the OECD technology classification system. The study found a positive and significant relationship between R&D expenditure and economic growth. A 1% increase in R&D expenditure contributes to sectoral growth by 0.05%. The study also analyzed the strength and direction of this relationship individually for all sub-sectors. Turkey's innovation performance was found insufficient because of the concentration of the manufacturing industry in low-

technology sectors. On the other hand, the study points out that the manufacturing industry is labor-intensive and has a weak innovation capacity. Şener (2010) investigated the relationship between R&D expenditures and production in the Turkish manufacturing industry using the data from 9 sub-sectors for the period 1992-2001 within the framework of an econometric model. The study determined a positive and significant relationship between R&D expenditures and manufacturing industry growth trends. Therefore, it confirms that the Turkish manufacturing industry has an endogenous growth trend. An expanded study based on manufacturing industry sub-sectors was implemented by Yılmaz and Yıldırım (2013). They investigated the effects of R&D expenditure and the number of employees participating in R&D activities on economic growth in 97 Turkish manufacturing industry sub-sectors for the period 2003-2007. The manufacturing sectors were classified into four categories according to their technology intensity: low, medium-low, medium-high, and high technology. The findings show that R&D expenditure contributes to growth, especially in low and medium technology intensity sectors. 1% increase in R&D expenditure leads to a 0.0484% increase in the manufacturing industry's productivity. Besides, the R&D coefficient of low technology intensity sectors was found to be 0.06. İltaş and Bulut (2017) examined the causality relationship between R&D expenditure and net sales revenues for five sectors (four of them are in the manufacturing industry) in Turkey from 1996-2013, conducting a bootstrap panel causality analysis. One-way causality from R&D expenditure to net sales revenues was found only in the textile and textile products industry. Besides, a one-way relationship from net sales revenues to R&D was found in the sectors such as food, beverage, tobacco, main metal and trimmed metal products, and wholesale and retail trade.

1.5.3. Empirical Studies on the Relationship Between R&D Expenditure and Export

This last sub-section is devoted to the studies aiming to establish a relationship between R&D and export. The studies examining the relationship between technological innovation and export in the manufacturing industries are

found in the literature. Uzay et al. (2012) tested the relationship between export performance and technological innovations in the Turkish manufacturing industry between the years 1995-2005 using panel data analysis. Due to data problems, the study was conducted for the whole manufacturing industry, not for its sub-sectors. R&D expenditure were considered as an input of innovation and taken as an explanatory variable. One and two-period lagged values of R&D expenditure were also included in the model since it will take a certain time to find a new product and to gain a commercial value. The effects of one-period lagged and two-period lagged R&D expenditure together with the current period were found positive, but the effects of lagged ones were much greater. Duman (2014) The effect of R&D expenditures in the manufacturing industry in the 2002-2011 period on various variables was examined using OLS. The study found that R&D expenditures have a positive effect both on sales and exports. Önder and Hatırlı (2014) aimed at analyzing export-led growth in Turkey. The quarterly data of the Turkish manufacturing industry for the period 1994-2009 were used to investigate the relationship between export and economic growth with the help of time series analysis. The number of patents was regarded to symbolize the R&D variable in the growth equation. It was stated that although the coefficient of the patent variable was positive, it will not contribute to growth because of insignificant statistical value. Perçin et al. (2017) investigated the relationship between export and innovation in 24 Turkish manufacturing industry sub-sectors over the period 2008-2013 with the help of panel data analysis. The study considered R&D intensity as an indicator of innovation. A dynamic model was established by taking two lagged values of R&D intensity as an explanatory variable. While the effect of R&D intensity on export intensity in the current period was negative, the effect of both one and two periods lagged values of R&D intensity was found to be positive. Additionally, a one-way causality relationship from innovation to export was confirmed. Dinçer (2021) The determinants of export performance in the Turkish manufacturing industry are estimated using the IV-2SLS and the system GMM methods using sectoral data covering the 2006-2018 period. The estimation results demonstrate that R&D positively affects export performance of the industry with a coefficient of 0.015. The study also analyzed the manufacturing industry by firm size (small, medium, large)

and found that R&D expenditures affect export only in large-size firms with a coefficient of 0,058.

One of the main purposes of R&D activities is to increase high technology exports. For this purpose, country-level studies that particularly examine the effects of R&D expenditure on high technology exports should be mentioned. Göçer (2013) aimed to examine the effects of R&D expenditures on the foreign trade balance by focusing on the variables of total exports, high technology exports, ICT exports, and economic growth in detail. This study was carried out for 11 Asian economies (Azerbaijan, China, South Korea, India, Kazakhstan, Malaysia, Pakistan, Russia, Singapore, Thailand, and Turkey) during the period 1996-2012 using panel data analysis. An important finding of the study was that a 1% increase in R&D expenditures affects high technology exports by 6.5%. Likewise, it affects ICT exports by 0.61% and economic growth by 0.43%. The effect of R&D expenditures on the total export and foreign trade balance was found to be positive but not statistically significant. Kılıç et al. (2014) analyzed the relationship between high technology product exports and R&D expenditures, emphasizing the value-added created by high technology products. The study was investigated with the data from G-8 countries (USA, Japan, Germany, United Kingdom, France, Italy, Canada, and Russia) for 1996-2011 using the panel data analysis method. They identified that R&D expenditures and real effective exchange rates positively affect high technology product exports. Moreover, the impact of R&D expenditures on high technology exports proceeds for two periods, and there is a two-sided causality relationship between high technology export and R&D expenditures. Biçen (2018) examined the relationship between R&D expenditures and high technology exports of 22 countries classified in low and middle-income categories according to the World Bank classification. The data between 2000-2015 were analyzed by the panel data analysis method and one and two periods of lagged R&D expenditures added to the model. The estimation result shows that 1% increase in R&D expenditures increases high technology exports by 0.26% in the same period and by 0.21% in the next period. The two-period lagged value of R&D expenditures was found statistically insignificant. Özçelik et al. (2018) investigated if there is a long-term

relationship between R&D expenditures and high technology exports for 10 OECD countries during the 1996-2014 periods using panel data analysis. The findings of the study show that a long-term cointegration relationship and two-sided causality relationship was determined between two variables.

Some of the recent studies investigating the relationship between total export and R&D expenditure were also listed: Köse and Yıldırım (2015) aimed to measure the impact of R&D expenditures and patent expenditures on the export performance of Turkey with the quarterly data between 2000 and 2010 using a simple regression analysis method. The findings indicate that a one-unit increase in R&D expenditure affects export by 0.08 units, and a one-unit increase in patent expenditure affects exports by 0.003 units. In addition, there is a two-sided causality relationship between R&D expenditures and export. Dumrul and Kılıçarslan (2018) tested the relationship between R&D activities and exports in 16 selected OECD countries for 2000-2015 using panel data analysis and FMOLS - DOLS estimators. As a result of the study, a long-term and positive relationship between R&D expenditures and export were found. The estimation coefficient of R&D expenditures was calculated as 0.45, indicating a strong relationship verified by both estimators. Acaravcı et al. (2019) investigated the impact of R&D expenditures on per capita real export in the Turkish economy for 1990-2014 with the help of the ARDL boundary test approach. The coefficients of the study indicate that R&D expenditures have a positive and significant effect on export both in the long term and in the short term. Canbay (2020) conducted an empirical study to find out the impact of R&D expenditures on the export performance of Turkey for the period 2004-2017 using the ARDL boundary test approach. The study found evidence that R&D expenditures increase export both in the long and short run.

CHAPTER TWO

THE GENERAL STRUCTURE AND THE TECHNOLOGICAL FEATURES OF THE TURKISH MANUFACTURING INDUSTRY

2.1. Introduction

This chapter presents the development phases, general and technological structure of the Turkish manufacturing industry. In both developed and developing countries, the manufacturing industries fulfill their responsibility of being the central sector of economic growth thanks to its rapid and efficient growth potential. As countries advance economically, they undergo a structural transformation from a natural resource-based economy to a production-based economy, marking the importance of the manufacturing industry. That is why the manufacturing industry functions as an indicator showing the development level of a country (Doğruel & Doğruel, 2008, p. 37). Rodrik emphasized the manufacturing industry's contribution to economic growth and stated that fast-growing countries have large and powerful manufacturing industries (Rodrik, 2006, p. 5-6).

The next stage of industrialization requires developing new products to increase capital deepening and productivity. Rodrik asserted that sustainable economic development should be based on product diversification backed by manufacturing activities (Rodrik, 2006, p. 3-4). Besides its contribution to the production-based economy, the manufacturing industry stands out with the resources it allocates to innovative activities, encourages the production of technological knowledge, and plays a central role in spreading technological dynamism to other sectors. In this respect, this chapter also provides a basic understanding of the current status of the Turkish manufacturing industry in the transition to a knowledge-intensive economy.

The rest of the chapter is organized as follows. Section 2.2 focuses on the Turkish economy and summarizes its development and industrialization process

historically. Section 2.3 focuses on the Turkish manufacturing industry as a whole and provides an overview of its structural features and trends using key indicators. Section 2.4 focuses on the manufacturing industry sub-sectors and classifies them according to their technology intensity, and aims to present the technological features and trends of the manufacturing industry through various structural and innovation indicators.

2.2. The Review of The Turkish Economy and Its Industrialization Process

Turkey's industrialization strategies and directions are an essential issue that should be reviewed within the structure of this thesis. Turkey has prioritized industrialization since its establishment and placed the manufacturing industry at the center of its production-based growth objectives. In this process, the manufacturing industry has been exposed to different industrialization strategies at different times depending on the policies implemented by the state.

We can divide the industrialization process of the Turkish economy into two periods, distinguished on the basis of policy implementations. In the pre-1980 period, except for a short liberal economy experience, statist, inward-oriented, and import-substitution strategies were predominantly implemented. After 1980, a structural transformation prioritizing an export-oriented, outward-looking, and the competitive economy was targeted (Sector Profiles of Turkish Industry, A General Outlook, 2004, p.1)

Turkey has gradually ceased to be a country with an agricultural-based economy with a rising share of the manufacturing industry in both GDP and overall production. In 2018, the Turkish manufacturing industry became the 16th largest industry in the world in terms of total value-added. It ranked 46th in per capita manufacturing industry value-added (Manufacturing Industry Policies, Special Expertise Commission Report, 2018, p.1).

2.2.1. The Turkish Economy in The Pre-1980 Period

The attempts to establish the basis for the economic policies of the Republic of Turkey began with the İzmir Economic Congress held in 1923. At the congress, it was emphasized that legal and institutional arrangements were necessary to get efficiency from economic activities. In this regard, an economic structure based on private entrepreneurship was envisaged where basic infrastructure and technical services such as education, transportation, communication, and credit facilities were provided by the state (Kepenek & Yentürk, 2001, p.34). The industry encouragement law was enacted in 1927 with the aim of directing the private sector to invest in the industry. In the first ten years of the Republic, industrial activities were carried out mainly in limited fields such as processing agricultural products, mining and weaving industries. Energy use in the industry was very low due to very primitive technologies. After all, the efforts to develop private industry were inconclusive, and a considerable industrialization process did not occur, but the view that the country should be industrialized was not abandoned (Kepenek & Yentürk, 2001, p.45-46).

In the 1930s and early 1940s, the Turkish economy became relatively closed and headed for statist and protectionist industrialization policies. This decade was characterized as the first industrialization period of the Republic concerning its aims and consequences (Boratav, 2005, p. 59). The import substitution industrialization strategy, which is generally described as the first industrialization move, was adopted. This strategy had two main objectives. The first is to develop domestic industries by implementing various protective and incentive policies. The second is to meet the demand for imported goods with domestic production. Due to the statist policies, the state invested in the industries where the private sector was insufficient, and industrialization was planned under the state's leadership. The first five-year industrialization plan (1934-1938) was adopted and implemented. The focus of the plan was on the domestic production of imported basic consumption goods. Industrial enterprises were established in locations close to raw material and labor resources. Rather than a macro perspective, the plan focused solely on state-led industrialization and investments. If we look at the industrial sector's performance,

significant progress was made in weaving, sugar, and cement. The establishment of iron and steel production was an extraordinary success. The aim of producing basic consumer goods by the domestic industry was achieved to a great extent. Foreign trade was mainly carried out within the framework of bilateral agreements and continued to give surplus except 1938. However, the weight of foreign trade in the economy decreased significantly towards the end of the period due to the war conditions and the policies implemented (Kepenek & Yentürk, 2001, p.68-78).

Table 2.1. Main Economic Indicators of The Turkish Economy (1930-1945).

Year	Export (Current Prices, Million TL)	Import (Current Prices, Million TL)	Foreign Trade Balance (Current Prices, Million TL)	Foreign Trade Volume/ GDP (%)	Growth (Chained Volume, %)	GDP (Chained Volume, Million TL)
1930	151,00	147,00	4,00	18,90	2,45	36.163,20
1931	127,00	126,00	1,00	18,10	8,21	39.132,96
1932	101,00	86,00	15,00	15,90	-10,62	34.977,96
1933	96,20	74,70	21,50	15,00	15,46	40.384,79
1934	92,10	86,10	6,00	14,70	6,30	42.928,40
1935	95,80	88,80	7,00	14,10	-3,02	41.629,96
1936	117,70	92,50	25,20	12,40	23,06	51.231,75
1937	138,00	114,40	23,60	14,00	1,52	52.010,82
1938	144,90	149,80	-4,90	15,60	9,46	56.931,57
1939	127,40	118,20	9,20	11,90	6,89	60.853,52
1940	111,40	68,90	42,50	7,50	-4,78	57.943,68
1941	123,10	74,80	48,30	6,60	-10,37	51.937,57
1942	165,00	147,70	17,30	5,00	5,51	54.800,79
1943	257,20	203,00	54,20	5,00	-9,79	49.433,91
1944	232,50	164,90	67,60	5,90	-5,08	46.923,60
1945	218,90	126,20	92,70	6,30	-15,28	39.752,22

Source: Kepenek & Yentürk (2001) and Presidency of Strategy and Budget (Economic and Social Indicators)

During the Second World War, industrialization and development were interrupted, and the economy contracted. After the war, The Turkey Economic Development Plan was prepared in 1947 to benefit from the Marshall aids. The plan

aimed to increase the weight of the private sector in the economy and envisaged that the agricultural sectors were the basis of the country's development. It gave priority to infrastructure investments such as transportation and energy to open up rural areas to markets (Kepenek & Yentürk, 2001, p.92). The plan's implementation was depended on the provision of the envisaged external resource, but it could not be put into practice as no external source was provided. Despite this, the critical feature of the plan was that the statist-protectionist industrialization strategy was definitely not on the agenda (Boratav, 2005, p. 98).

The period between 1946-1960 was called the liberal economy period. The previous period's protectionist, inward-oriented, and foreign trade balance based economic policies were gradually abandoned. Rather than inward-looking industrialization, a foreign market-oriented development approach, which prioritizes agriculture, mining, infrastructure, and construction sectors, mostly prevailed. The distinguishing feature of this period was the emergence of a new economic structure. The dependence on foreign aid, credit, and foreign capital inflows emerged due to increasing import volume and trade deficits (Boratav, 2005, p. 94). The economy experienced rapid growth between 1946 and 1953. Because of the remarkable expansion in agricultural production, the share of agriculture in national income increased while industrial production decreased. These outcomes reflected integration with the world economy based on specialization. The foreign trade balance deteriorated significantly in this period and had a continuous deficit except in 1946. 1946 was the last year in which the foreign trade surplus of the Turkish economy was recorded (Boratav, 2005, p.101-102). Industrial production had gained vitality with agricultural development and rapid urbanization. Private sector industrial production also developed rapidly in this period, with the efforts to meet the demand for basic consumption goods (weaving, clothing, food, beverage) and non-durable consumption goods with domestic production. Thus, the first phase of import-substitution industrialization was completed. In a way, this was a transition period in which private sector industrial production was strengthened, and public enterprises remained productive. Significant rises in some intermediate goods (cement, pharmaceuticals, chemicals, construction materials) were achieved.

Nevertheless, there were no significant improvements in durable consumer goods and investment goods sectors (Kepenek & Yentürk, 2001, p.109-112). Continuous foreign trade deficits were compensated with foreign aid, borrowing, and foreign exchange and gold reserves at first. After 1953, with the emergence of foreign exchange shortage and payment difficulties, imports were restricted, bilateral trading agreements were made with some countries. As the foreign trade deficit continued, the devaluation was made in 1958 as a stabilization measure. A one-to-one relationship between foreign trade and economic growth emerged during this period as production became seriously dependent on imports and external resources (Kepenek & Yentürk, 2001, p.120-123).

Table 2.2. Main Economic Indicators of The Turkish Economy (1946-1960).

Year	Export (Current Prices, Million TL)	Import (Current Prices, Million TL)	Foreign Trade Balance (Current Prices, Million TL)	Foreign Trade Volume/ GDP (%)	Growth (Chained Volume, %)	GDP (Chained Volume, Million TL)
1946	432,10	223,90	208,20	9,60	32,08	52.503,56
1947	625,20	685,00	-59,80	17,40	4,15	54.680,94
1948	551,00	770,10	-219,10	13,90	16,36	63.628,73
1949	693,90	812,30	-118,40	16,60	-4,98	60.456,97
1950	737,60	799,90	-62,30	15,90	9,40	66.139,06
1951	879,40	1.125,80	-246,40	17,70	12,79	74.600,50
1952	1.016,20	1.556,60	-540,40	19,20	11,95	83.516,03
1953	1.109,00	1.491,10	-382,10	16,70	11,23	92.890,78
1954	937,80	1.399,40	-461,60	14,30	-2,87	90.226,23
1955	877,40	1.393,40	-516,00	11,90	8,08	97.520,76
1956	854,00	1.140,60	-286,60	9,50	3,25	100.692,50
1957	966,60	1.112,00	-145,40	7,10	7,92	108.667,30
1958	692,40	882,30	-189,90	4,50	4,56	113.621,10
1959	990,60	1.310,00	-319,40	5,30	4,62	118.873,10
1960	1.721,20	2.213,70	-492,50	8,40	2,91	122.331,00

Source: Kepenek & Yentürk (2001) and Presidency of Strategy and Budget (Economic and Social Indicators)

The years between 1960 and 1980 were the period when import substitution industrialization was applied in a more conscious, strict, and planned manner. The

efforts to reduce the dependence on expensive products imported from abroad and establish a domestic industry to manufacture these products continued and accompanied by import controls and tariffs. This period, in which the state played an important regulatory role, was also known as a planned development period. Unlike the plans implemented before 1960, four development plans were prepared for the entire economy. They included all aspects of economic and social development at the macro level. Apart from public investments, private investments benefiting from government incentives and supports had to be compatible with development plans. All four development plans were prepared for a long-term strategy, emphasizing the domestic production structure and prioritizing industrialization (Kepenek & Yentürk, 2001, p.143-144). Development plans also largely determined investment policies and resource allocations in the economy. While private capital was involved in producing durable consumer goods, the public sector undertook the production of intermediate goods and investment goods (Kepenek & Yentürk, 2001, p.148). In line with import substitution industrialization, a three-stage strategy was planned for the economy's self-sufficiency. Targets were set for the domestic industry, first for producing durable consumer goods, then for the production of intermediate and investment goods. In this way, it was expected that the need for foreign currency would be reduced gradually. As this goal was achieved only for consumer goods, foreign dependency on production inputs and capital goods step by step increased. The import substitution approach was expected to reduce the foreign dependency of the economy. The opposite happened. Import-substitution industries became chronically foreign-dependent. Purchasing difficulties from abroad also triggered a decrease in production. The foreign trade deficit and the balance of payments deficit widened continuously. The export/import coverage ratio decreased steadily. Despite all these problems, a stable and high growth rate was achieved in the economy due to domestic savings in the early periods and the workers' remittances and foreign loans in the later periods. Import substitution policies implemented during this period failed to achieve the expected targets. Turkey had focused on import-substitution strategy until 1980 and resolutely aimed at domestic industrialization. Because of severe difficulties in the balance of payments and the decrease in production, Turkey had to abandon these policies (Kepenek & Yentürk, 2001, p.361-363).

Table 2.3. Main Economic Indicators of The Turkish Economy (1960-1980).

Year	Export (Million USD)	Import (Million USD)	Foreign Trade Balance (Million USD)	Foreign Trade Volume/GDP (%)	Growth (Chained Volume, %)	GDP (Chained Volume, Million TL)
1961	347,00	510,00	-163,00	7,86	1,72	124.435,26
1962	381,00	622,00	-241,00	7,91	6,07	131.993,67
1963	368,00	688,00	-320,00	7,18	9,43	144.435,66
1964	411,00	537,00	-126,00	6,07	4,14	150.417,61
1965	464,00	572,00	-108,00	6,16	2,62	154.351,89
1966	490,00	718,00	-228,00	6,03	11,71	172.431,41
1967	523,00	685,00	-162,00	5,43	4,50	180.193,72
1968	496,00	764,00	-268,00	5,08	6,65	192.179,53
1969	537,00	801,00	-264,00	4,83	4,08	200.022,64
1970	588,00	948,00	-360,00	5,93	3,23	206.490,29
1971	677,00	1.171,00	-494,00	7,97	5,57	217.984,76
1972	885,00	1.563,00	-678,00	8,34	7,43	234.172,09
1973	1.317,00	2.086,00	-769,00	9,21	3,26	241.811,19
1974	1.532,00	3.778,00	-2246,00	10,42	5,59	255.339,24
1975	1.401,00	4.502,00	-3101,00	9,26	7,17	273.657,53
1976	1.960,00	4.872,00	-2912,00	9,37	10,46	302.285,57
1977	1.753,00	5.506,00	-3753,00	8,70	3,41	312.583,12
1978	2.288,00	4.369,00	-2081,00	7,30	1,50	317.281,25
1979	2.261,00	4.815,00	-2554,00	6,35	-0,62	315.300,94
1980	2.910,00	7.513,00	-4603,00	11,22	-2,45	307.584,57

Source: Presidency of Strategy and Budget (Economic and Social Indicators)

2.2.2. The Turkish Economy in The Post-1980 Period

Following the rise of the neoliberal policies in the world and the Turkish government's economic stability decisions on January 24, 1980, the economy witnessed a major structural change. Turkey abandoned the import substitution strategy and adopted an export-oriented industrialization strategy. In this model, as the economy's driving force comes from external demand, the industry should gain a competitive advantage in the world market by focusing on technological development, productivity, and factor costs. Government adopted policies that would increase market efficiency. In this strategy, which attaches great importance to

economic and commercial integration with the world, the share of export in GDP is became a critical issue.

The Turkish government targeted a liberal economic system by removing market price controls and the barriers to foreign trade. A distinctive feature of this period was reducing the influence of the public sector in the economy and leaving economic development to market conditions. As an extension of this policy, industrialization was also expected to occur within market conditions (Kepenek & Yentürk, 2001, p.209). To this end, incentives were provided at each investment, production, and export stage to increase the export of industrial products. The exchange rate policy was used to gain a competitive advantage in trade and to increase foreign exchange inflows.

Structural changes also constitute a breaking point for the Turkish manufacturing industry. After that date, competitive industrialization based on export and technological progress has emerged as the main concern of the Turkish manufacturing industry. With the adoption of this new perspective, the manufacturing industry started to contribute significantly to the export performance of the economy.

Towards the end of the 1980s, the momentum of the reform process weakened, and export-led growth reached its economic and social boundaries. The share of industrial products in exports and exports in national income increased significantly. However, the foreign trade balance continued to have a deficit. Along with the high growth rates of the Turkish economy, the growth performance of the manufacturing industry was also noteworthy. The industry reached this performance with high-capacity utilization, although it received relatively less investment due to the concentration of public investments on unproductive infrastructure investments. Within this period, an ideal momentum in industrialization in terms of expansion, efficiency, and technology was not achieved. Even export could not be placed on a reliable basis, and a proper competitive advantage could not be obtained.

Financial liberalization, which started to be implemented after 1989, has had a significant impact on the macroeconomic balances of the Turkish economy. After

liberalization, the inflow of foreign capital into the country accelerated. This was accompanied by the deterioration of fiscal discipline and rising dependence on imports, making the Turkish economy prone to financial crises. The imbalances brought about by rising interest rates and high inflation negatively affected public infrastructure investments and manufacturing industry investments. This process reduced the competitive power of the manufacturing industry (Kepenek & Yentürk, 2001, p.365).

Table 2.4. Main Economic Indicators of The Turkish Economy (1981-2000).

Year	Export (Million USD)	Import (Million USD)	Foreign Trade Balance (Million USD)	Foreign Trade Volume/GDP (%)	Growth (Chained Volume, %)	GDP (Chained Volume, Million TL)
1981	4.703	8.567	-3.864	35,47	4,86	322.522,75
1982	5.890	8.518	-2.628	21,62	3,56	334.015,38
1983	5.905	8.895	-2.990	18,44	4,97	350.619,30
1984	7.134	10.044	-2.910	22,70	6,71	374.152,72
1985	7.959	10.935	-2.976	21,62	4,24	390.022,23
1986	7.457	10.475	-3.018	18,40	7,01	417.370,49
1987	10.190	13.396	-3.206	21,15	9,49	456.961,09
1988	11.662	13.475	-1.813	21,37	2,12	466.650,27
1989	11.625	15.815	-4.190	19,22	0,25	467.824,56
1990	12.959	22.407	-9.448	17,58	9,26	511.123,16
1991	13.593	20.883	-7.290	17,28	0,93	515.858,78
1992	14.715	22.791	-8.076	17,85	5,98	546.729,25
1993	15.345	29.426	-14.081	18,78	8,04	590.697,32
1994	18.106	22.273	-4.167	23,38	-5,46	558.470,85
1995	21.636	34.788	-13.152	25,38	7,19	598.631,74
1996	32.067	42.331	-10.264	31,10	7,01	640.567,78
1997	32.110	47.158	-15.048	31,80	7,53	688.794,85
1998	30.852	44.779	-13.927	28,27	3,09	710.091,47
1999	29.135	38.802	-9.667	28,08	-3,39	686.024,30
2000	30.923	52.882	-21.959	32,11	6,64	731.576,74

Source: Presidency of Strategy and Budget (Economic and Social Indicators)

A period full of financial turmoil and crises was experienced due to the severe impacts of speculative capital movements in the 1990s and early 2000s. The cyclical

policies were implemented due to the search for stability in the economy. Fiscal discipline was seriously deteriorated due to structural reasons, rising interest rates, and borrowing. Interest rates were in a vicious cycle by constantly rising. The expectations that the economy administration would increase liquidity and reduce interest rates triggered an upsurge in demand for foreign exchange. Upon this, the government had to announce an economic stabilization program on April 5, 1994, to reestablish the balance (Kepenek & Yentürk, 2001, p.485). These decisions were the beginning of the IMF programs in the 1990s. A new era in which the IMF and the World Bank were determinant in economic administration started. After the 1994 agreement, in 1998, a close monitoring agreement was signed with the IMF. In 2000, the anti-inflation program was put into practice. In this program, structural reforms were targeted in public sector financing, and the acceleration of privatization gained importance. This program ended due to the successive crises in November 2000 and February 2001. In the 1990s, the competition in exports could only be achieved by reducing the value of the domestic currency and labor cost. Short-term cycles of expansion, stagnation, and contraction were experienced in the economy.

In line with the IMF's views, the program for transition to a strong economy was announced in 2001. The program had sustainable growth, reducing inflation to single-digit numbers, providing income distribution and social justice targets. A series of structural reforms were envisaged to eliminate the problems of distrust and instability in the economy. As the problems in the economy did not end, it was decided to implement a strengthened medium-term program. In 2002, a new stand-by agreement was signed with the IMF. Strong and stable growth, low inflation, and new employment were accepted as the main targets. A serious fall in inflation was achieved during this period, breaking the chronic inflationary process. Turkey's growth rate showed 27 consecutive quarters of positive growth throughout 2002-2008. Export boomed from 36 million USD in 2002 to 132 million USD in 2008. The Turkish economy achieved remarkable growth in the 2000s due to the reforms, macroeconomic policy measures, and the abundance of liquidity in the international markets. However, this growth created an economic structure fed by the import volume triggered by domestic consumption and investment. Consequently, a

troubling situation emerged in which foreign trade deficit and the dependence on foreign capital were constantly increasing.

2.2.3. The Composition of Goods in Foreign Trade

Until 1980, Turkey laid out industrialization and production objectives according to the broad economic categories classification in which manufactured products are organized as capital, intermediate, and consumer goods. Even though strategies and objectives changed after that date, illustrating the composition of goods in export and import sufficiently reflects the industrialization stage of the Turkish economy. The recent performance of the Turkish economy is worth understanding in this respect. Throughout 2000-2019, there have been changes in Turkey's import composition. However, these were not major changes, but important changes to mention about. The share of intermediate goods in imports increased significantly from 66% in 2000 to 78% in 2019 and maintained its average of 72% during this period. The share of capital goods and the share of consumption goods in import have been in the direction of decline, as seen in the import chart on the right in Figure 2.1. The share of capital goods accounts for 16% of imports and 10% of export on average. This chart clearly shows that our economy is highly dependent on imported intermediate goods.

Figure 2.1. Export and Import by Broad Economic Categories in The Turkish Economy (2000-2019).



Source: Turkstat

Although the composition of economic goods did not change much for imports, significant changes occurred in the composition of exported goods, and we can see this in the export chart on the left. This chart also reflects a particularly remarkable development for the Turkish economy. Until 2007, exports of consumer goods were predominant in the economy. Thereafter, intermediate goods gained weight in export. This is a positive indicator that reflects the developing productive capacity of the industry. Intermediate goods maintained their export weight with a share of 47% in 2019. The share of consumer goods in exports was recorded as 41% in 2019. The export table shows that the Turkish industry has progressed in the production of intermediate goods and consumer goods.

2.2.4. Research and Development Activities

R&D activities of the manufacturing industry sub-sectors will be unfolded in Section 2.4. Prior to this, it would make sense to briefly mention about R&D and innovation activities in the Turkish economy.

Until the 1990s, knowledge production was mainly carried out within universities, but university-industry cooperation was not sufficiently developed. Except for defense industry technologies, there had not been enough activity in R&D and innovation in industrial organizations. In the 1990s, KOSGEB and TTGV were established, and support programs to direct the private sector to R&D activities put into practice. Significant momentum has been gained with TÜBİTAK R&D support programs. Governmental organizations have implemented human resources development programs to have qualified researchers. In the 2000s, in order to make firms more competitive, support programs that encourage university-industry cooperation and R&D cooperation were focused (Strengthening R&D and Innovation Ecosystem, Special Expertise Commission Report, 2018, p.16-17).

R&D activities are often questioned regarding R&D expenditure and the number of R&D personnel. The main indicator of the knowledge-intensive economy is the share of R&D expenditure in GDP. Although the ratio of R&D expenditure to GDP is far below the level of developed countries, a significant increase in this ratio

has been achieved in the last two decades. R&D expenditure to GDP ratio of the Turkish economy was 0.53% in 2001, doubled as of 2020, and was recorded as 1.09%, according to Turkstat. Total R&D expenditure reached 54.9 trillion TL in 2020, whereas it corresponded to 1.3 trillion TL in 2001. A massive increase has also taken place in the number of R&D personnel. The full-time equivalent of R&D personnel was 27,698 in 2001, and it rose significantly to 199,371 in 2020.

Table 2.5. Total R&D Expenditures of The Turkish Economy (2001-2020).

Year	Total R&D Expenditure (Million TL)	Financial and non-financial corporations (Million TL)	Government (Million TL)	Higher education (Million TL)
2001	1.291,89	435,86	95,10	760,93
2002	1.843,29	528,96	129,29	1.185,04
2003	2.197,09	510,35	229,33	1.457,41
2004	2.897,52	700,60	230,49	1.966,43
2005	3.835,44	1.297,59	443,16	2.094,69
2006	4.399,88	1.629,09	513,80	2.256,99
2007	6.091,18	2.513,49	642,84	2.934,85
2008	6.893,05	3.048,50	823,65	3.020,90
2009	8.087,45	3.235,27	1.016,52	3.835,66
2010	9.267,59	3.942,91	1.060,68	4.264,00
2011	11.154,15	4.817,27	1.263,50	5.073,37
2012	13.062,26	5.891,21	1.436,92	5.734,13
2013	14.807,32	7.031,52	1.543,49	6.232,31
2014	17.598,12	8.760,02	1.705,40	7.132,70
2015	20.615,25	10.308,74	2.130,77	8.175,74
2016	24.641,25	13.359,01	2.338,37	8.943,87
2017	29.855,48	16.980,84	2.858,44	10.016,21
2018	38.533,67	23.289,37	3.559,21	11.685,09
2019	45.953,69	29.500,71	3.044,49	13.408,49
2020	54.956,82	35.623,33	3.716,72	15.616,76

Source: Turkstat

The components of total R&D expenditure are as follows: In 2001, 59% of R&D expenditure was incurred by the higher education sector, 34% by financial and non-financial corporations, and the remaining 7% by the government. In 2020, despite small fluctuations before 2020, the share of government in total R&D expenditure remained the same at 7%. However, a fundamental change occurred in

the composition. In 2001, the higher education sector dominated total R&D expenditure with 59%. By 2020, financial and non-financial corporations became dominant, reaching 65% share. The share of the higher education sector dropped to 28%. This indicates that the center of R&D activities in the Turkish economy shifted from universities to the real sector during this period.

According to Turkstat data, in 2020, 35.6 billion TL of 54.9 billion TL total R&D expenditure belongs to financial and non-financial corporations, 15.6 billion TL to the higher education sector, and the remaining 3.7 billion TL to the government sector. The manufacturing industry made 20.3 billion TL of 35.6 billion TL R&D expenditure of financial and non-financial institutions. This amount, which corresponds to 37% of total R&D expenditure and 57% of R&D expenditure of financial and non-financial institutions, also clarifies the importance of the manufacturing industry in innovation.

2.3. The General Structure of the Manufacturing Industry

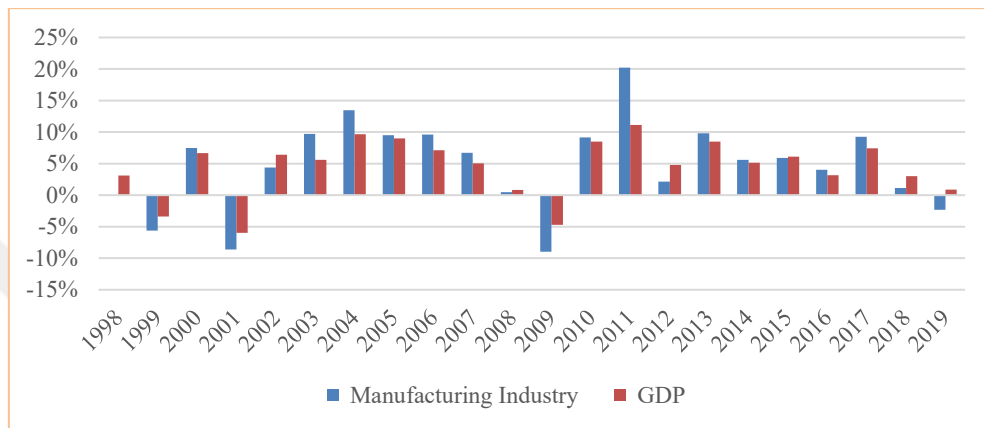
This section presents the general structural features and trends of the manufacturing industry will be presented. Some selected key indicators are used to reflect the performance of the manufacturing industry for the past two decades. These indicators can be listed as growth rate, the number of employees, the number of enterprises, fixed investment, capacity utilization rate, foreign direct investment, production value, value-added, export, and import. The statistical data of each indicator will be presented visually with the help of tables and graphs and supplemented by a brief description and interpretation.

2.3.1. Growth

The growth of the economy and the manufacturing industry between 1998 and 2019 was depicted together in Figure 2.2. to make a comparison with ease. Both indicators dropped their lowest level in 2009. They shrunk together during the crisis years and expanded immediately after the crisis, so the two variables seem to always move in the same direction. The average GDP growth rate and the average

manufacturing industry growth rate were recorded as 4.5% and 4.9%, respectively, between 1998 and 2019. These parallel movements over the entire period could stem from the fact that the manufacturing industry was the biggest contributor to GDP.

Figure 2.2. Growth Rates of The Turkish Economy and Manufacturing Industry (1998-2019).



Source: Turkstat

As the main productive sector of the Turkish economy, the share of the manufacturing industry in GDP also needs to be mentioned. Even in times of crisis such as 2001 and 2008, the manufacturing industry's share in GDP did not change too much. It has drawn a stable picture for the 1998-2019 period, corresponding to an average of 17.3% of GDP. The manufacturing industry continued to make the largest contribution to GDP compared to other economic activities (agriculture, construction, finance, education, etc.) throughout the period, despite a slight downward deviation from its pre-2000 position.

Table 2.6. The Share of Manufacturing Industry in GDP of Turkey (1998-2019).

1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
22,3	20,0	18,7	17,7	16,9	17,1	16,9	16,9	17,1	16,8	16,3
2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
15,2	15,1	16,4	15,8	16,3	16,8	16,7	16,6	17,6	19,0	18,3

Source: Turkstat

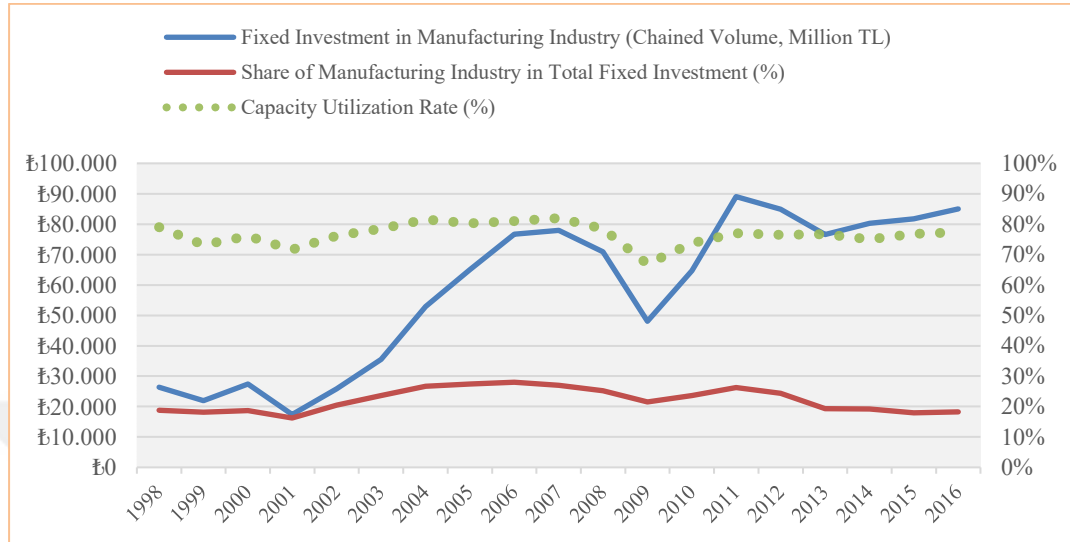
2.3.2. Investment, Enterprises, and Employment

The growth performance of the Turkish economy has been closely linked to its accessibility to resources such as investment, labor force, and raw materials. Investment accelerates growth and development by providing the basis for structural changes. The relatively capital-intensive production structure of the manufacturing industry makes fixed capital investments more critical. In this respect, it is necessary to pay attention to how much the manufacturing industry has benefited from labor and investments in recent years. Figure 2.3., Figure 2.4., and Figure 2.5. illustrate the changes and trends in these inputs for the period in question.

Fixed capital investments in the manufacturing industry, its share in total fixed capital investments, and capacity utilization rates are presented in Figure 2.3. for 1998-2016. The periods 2001-2007 and 2010-2011 can be defined as the development periods of investments that increase the manufacturing industry productivity. From 2001 to 2007, investments in the manufacturing industry increased rapidly. After a short period of contraction that began with the 2008 crisis, a rapid recovery occurred, the manufacturing industry managed to regain its previous level in 2011. Then, total fixed investments showed a stable trend. The share of the manufacturing industry in total fixed capital investments exhibited an upward trend until 2011, then, showed a downward trend up to 2016. The share of the manufacturing industry in total fixed capital investment was recorded as 22% on average between 1998 and 2016.

Capacity utilization rate measures how much a firm's production capacity is used. Firms can take advantage of the idle capacity to rapidly increase production and take advantage of costs without further investment. The capacity utilization rate did not fluctuate significantly between 1998 and 2016, except for the 2009 crisis, with the lowest rate of 67%. This fall stopped an apparent increasing trend of capacity utilization in the manufacturing industry. The average capacity utilization rate was calculated as 77.7% during this period.

Figure 2.3. Fixed Investment and Capacity Utilization Rate in Manufacturing Industry (1998-2016).



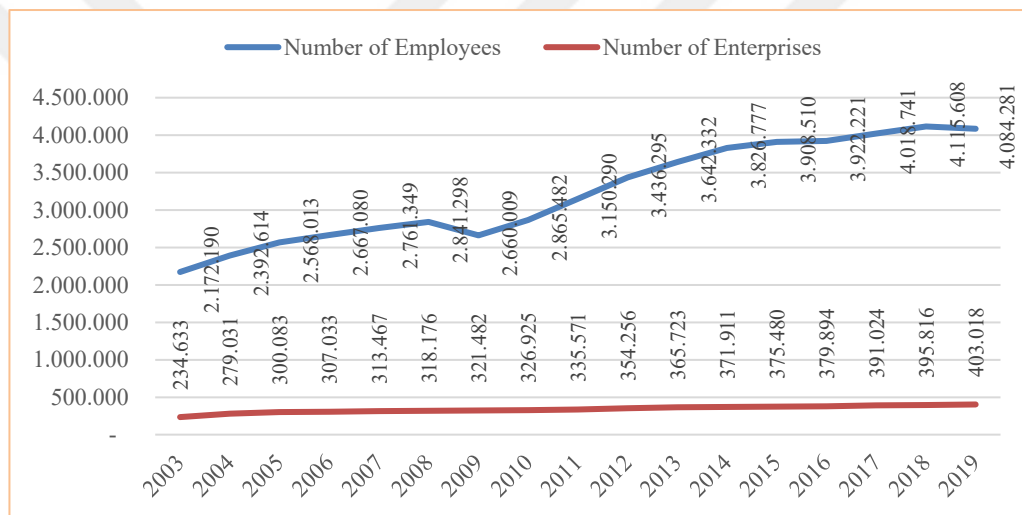
Source: Presidency of Strategy and Budget (Economic and Social Indicators)

The manufacturing industry has managed to occupy an important place in the Turkish economy regarding employment and enterprises. In the recent period, the industry maintained this feature, reflecting the distinctive character of being a developing country. Figure 2.4. shows the numbers of employees and enterprises in the manufacturing industry between 2003 and 2019. The number of enterprises increased from 234,633 in 2003 to 403,018 in 2019, corresponding to a 72% increase over 16 years. The highest increase was achieved in the years 2004, 2005, and 2012. The number of employees increased from 2,172,190 in 2003 to 4,048,281 in 2019, corresponding to an 88% increase. While the number of employees decreased only in 2009 and 2019, the highest decrease was in the 2009 crisis year with 181,289 employees. The steady growth trend in the number of enterprises and the number of employees indicates a gradual increase rather than a big leap in the capacity of the manufacturing industry.

Foreign Direct Investment has an undeniable role in increasing the production capacity of a country, as well as has the potential to develop its innovativeness through technology transfer. Nevertheless, Turkey did not receive sufficient contribution from FDI. The industry's share of in total FDI and the amount of FDI received by the manufacturing industry between 2007 and 2019 are shown in Figure

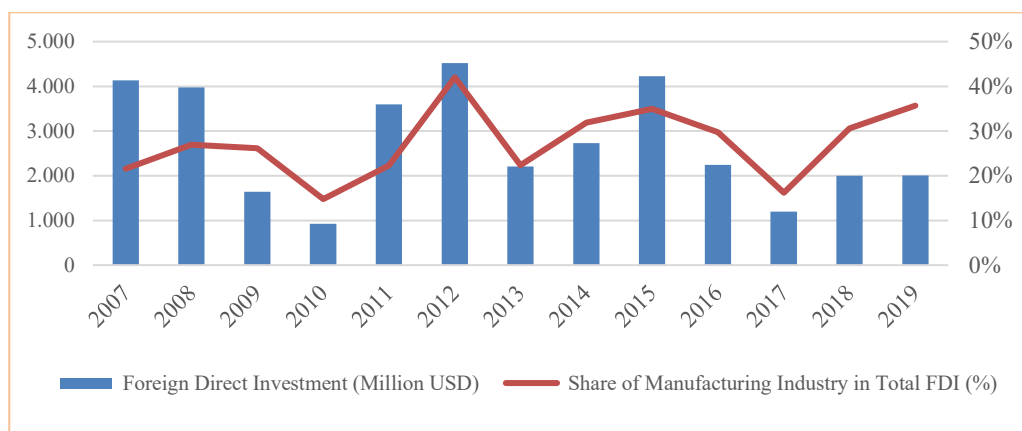
2.5. Both variables indicate an unstable image by showing constant fluctuations for the mentioned period. 35,394 million USD was the total amount of foreign direct investment coming to the manufacturing industry, corresponding to an annual average of 2,723 million USD, which can be considered a very low level. The average share of the manufacturing industry from FDI inflows into Turkey was 27% in this period. In this respect, the manufacturing industry ranks in the second position after the services sector, which receives the most FDI in Turkey.

Figure 2.4. Number of Enterprises and Number of Employees in Manufacturing Industry (2003-2019).



Source: Turkstat

Figure 2.5. Foreign Direct Investment in Manufacturing Industry (2007-2019).



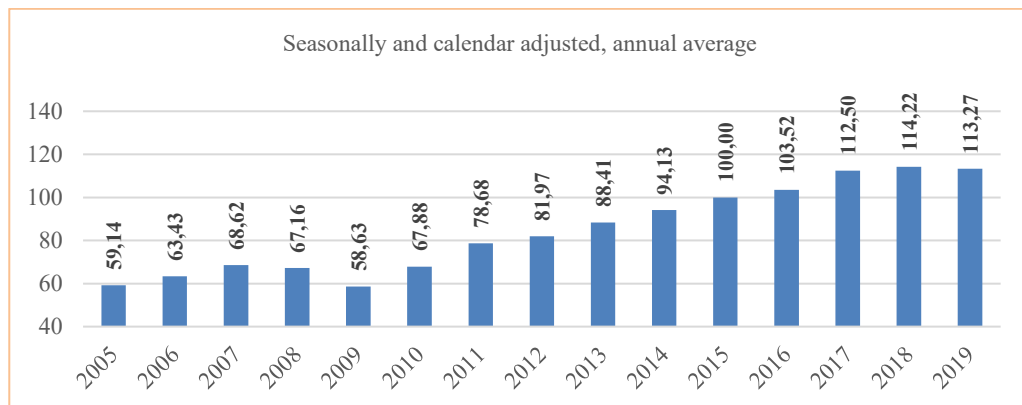
Source: Presidency of Strategy and Budget (Economic and Social Indicators)

2.3.3. Production and Value-Added

After mentioning the main inputs used in production, it is necessary to evaluate the outputs of the manufacturing industry. For this purpose, some key output indicators such as production index, production value, value-added, import, and export will be used.

The production index is a critical indicator used to measure real outputs and depicted in Figure 2.6. for the manufacturing industry between 2005 and 2019. The production value, which was calculated as 59.14 in 2005, increased to 113.27 in 2019, and a 92% increase in production was achieved. With the adverse effect of the 2008 global economic crisis, the production shrunk significantly in 2008 and 2009. The manufacturing industry recovered rapidly after the crisis and this was accompanied by a significant increase in production in 2010 and 2011. During 2005-2019, the manufacturing industry production followed up an expansion path, which is fueled by the increase in investments, labor force, and export volume. If we disregard sharp contractions in 2008 and 2009. From the production index chart below, we can infer that the manufacturing industry has strengthened its production structure, especially in the last 10 years.

Figure 2.6. Production Index of Manufacturing Industry (2005-2019).

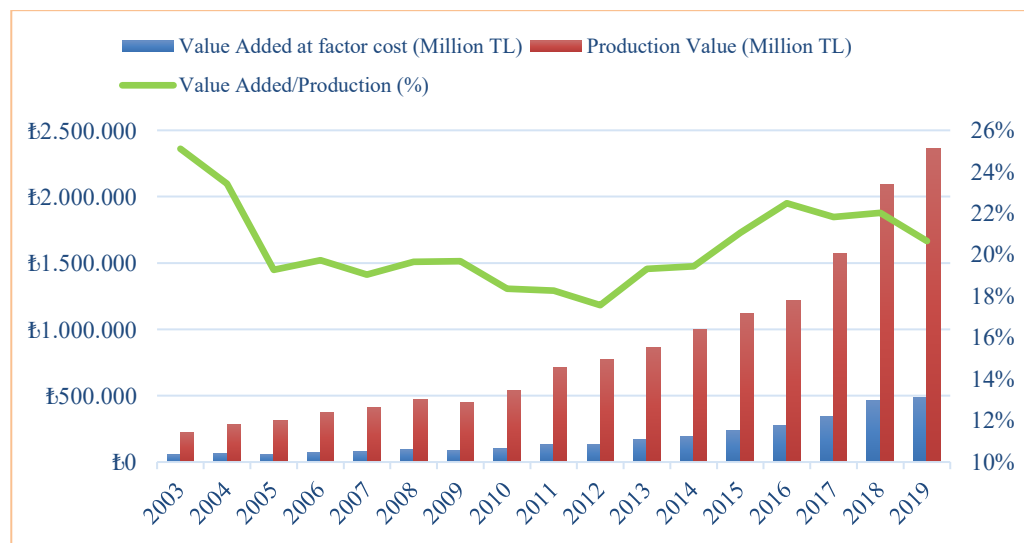


Source: Turkstat

Another critical output indicator that measures the productivity of an economy is value-added. Value-added refers to how much revenue is generated by

firms after covering the cost of production. Figure 2.7. shows the production value, value-added, and the value-added/production ratio in the manufacturing industry between 2003 and 2019. The ratio of value-added to production started to decline continuously between 2003 and 2012, then, showed an upward trend until 2016. Despite this achievement, the manufacturing industry has not yet reached the value-added ratio that it succeeded in 2003. The decline in the manufacturing industry value-added until 2012 overlaps with the decline in the manufacturing industry's share in GDP until 2012, as can be seen in Table 2.6. This coincidence can be interpreted as the result of the low performance of the manufacturing industry in creating value-added in the relevant period. While the value-added/production ratio was 25% in 2003, it was recorded as 21% in 2019, the average ratio for this period was calculated as 20%. The amount of value-added produced by the manufacturing industry increased from 56,022 million TL in 2003 to 488,797 million TL in 2019. The manufacturing industry production value increased from 223,117 million TL in 2003 to 2,365 billion TL in 2019. Despite the significant increase in production value and value-added, the manufacturing industry did not achieve a distinguishable improvement in the value-added/production ratio between 2003 and 2019.

Figure 2.7. Production Value and Value-Added in Manufacturing Industry (2003-2019).



Source: Turkstat

2.3.4. Export and Import

The foreign trade volume of the Turkish economy has been determined largely by the manufacturing industry activities. In this regard, it would be meaningful to mention the overall economy's import and export performance and the role of the manufacturing industry in this performance.

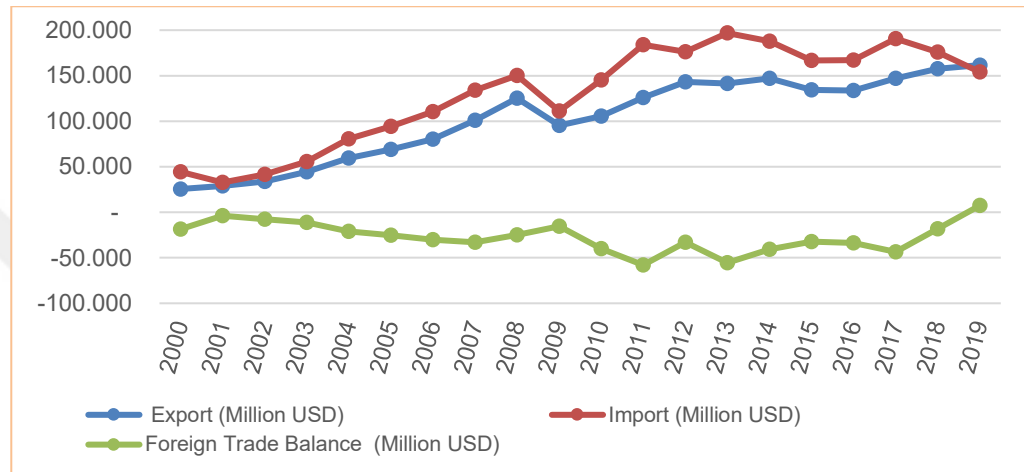
The foreign trade balance of the Turkish economy continued to have a deficit in the period 2000-2019 and maintained to negatively affect the balance of payments. Foreign trade balance gradually worsened until 2013. After 2013, a downward trend in the trade deficit started with the depreciation of the Turkish Lira. Thus, the deficit, recorded as 106 billion USD in 2011, lowered to 31 billion USD in 2019. The Turkish economy gave an annual average deficit of 55 billion USD in the last two decades. The Turkish economy's export/import coverage ratio showed a constantly fluctuating structure. It varied between 51% (the lowest rate in 2011) and 85% (the highest rate in 2019), corresponding to 67% on average in this period. The depreciation of the Turkish lira in recent years has made a positive contribution to the economy's export/import coverage ratio.

The manufacturing industry has always been the dominant sector in the foreign trade of the Turkish economy. The manufacturing industry carried out the majority of the export between 2000 and 2019 with an average of 94%. On the import side, the share of the manufacturing industry followed a relatively fluctuating course. It remained at an average of 79% due to the partial weight of the mining and quarrying sector.

Export-Import performance and foreign trade balance of the manufacturing industry is depicted in Figure 2.8. Foreign trade volume increased continuously until 2014, except for 2009. In 2009, with the negative impact of the global crisis, both imports and exports contracted by approximately 25%. As can be seen from the chart below, except for 2018 and 2019, the import and export of the manufacturing industry moved together. For the last two years, exports increased by 10%, while imports contracted by 19% because of the depreciation of the Turkish lira. Exports,

which amounted to 25,518 million USD in 2001, increased more than six times, reaching 161,607 million USD in 2019. Import, which were 44,200 million USD in 2000, increased approximately three and a half times and reached 154,254 million USD in 2019.

Figure 2.8. Export and Import of Manufacturing Industry (2000-2019).



Source: Turkstat

Foreign trade balance deteriorated seriously against the manufacturing industry especially after 2004. Imports boomed in 2010 and 2011 in two consecutive years after the crises. 2011 was the year when the foreign trade deficit peaked in terms of both the manufacturing industry and the overall economy, and it was 57,968 million USD for the manufacturing industry. However, due to the stabilization trend experienced in the recent years, a small but significant surplus (7,354 million USD) in the manufacturing industry foreign trade balance was recorded in 2019, mainly due to the depreciation of the Turkish Lira. Between 2000-2019, the average foreign trade deficit of the manufacturing industry amounted to 26,955 million USD.

2.4. The Technological Structure of the Manufacturing Industry

This section aims to present the technological features and trends of the manufacturing industry sub-sectors through key indicators. Instead of handling the sectors one by one, they were classified according to their technology intensities and evaluated accordingly.

Innovation indicators such as R&D expenditure, R&D personnel, Ph.D. and master's degree R&D personnel, number of patents, and various structural indicators such as number of employees, number of enterprises, production, value-added, import and export will be evaluated by dividing the sectors into categories as low, medium-low, medium-high, and high according to technology intensity. Since the data on the manufacturing industry sub-sectors are identical and coherent after 2009 because of NACE classification system, the statistical data used in the charts of this section covers the period between 2009-2020.

2.4.1. Classification of the Manufacturing Industry Sub-Sectors

Manufacturing industry sub-sectors will be classified according to the statistical classification of economic activities in the European Community system (NACE). As of 2009, the NACE classification system has changed by switching from NACE Rev 1.1 to NACE Rev. 2. Although the general features of NACE remain unchanged, the introduction of some new concepts at the section level makes it impossible to easily perform an overall comparison between NACE Rev. 2 and its previous version (European Statistical Office, 2008, p.47). Manufacturing industry (Section C), one of the twenty-one sections of the NACE Rev.2, consists of 24 divisions corresponding to two-digit sub-sectors coded with numbers starting from 10 to 33. These sub-sectors are listed in Table 2.7. below.

Eurostat's technology intensity classification system, which is compatible with Nace Rev.2 two-digit classification, is adopted to evaluate the manufacturing industry sub-sectors according to their technology intensities. This classification will help us better understand what kind of technology intensity dominates the Turkish manufacturing industry in terms of resource allocation, output, foreign trade, and innovation. Thus, the industry's position in the transition to knowledge-intensive economy will be better understood. Table 2.7. shows the technology intensity of the each manufacturing industry sectors.

Table 2.7. Nace Rev.2 Classification and Technology Intensity Classification of Manufacturing Industry Sub-Sectors.

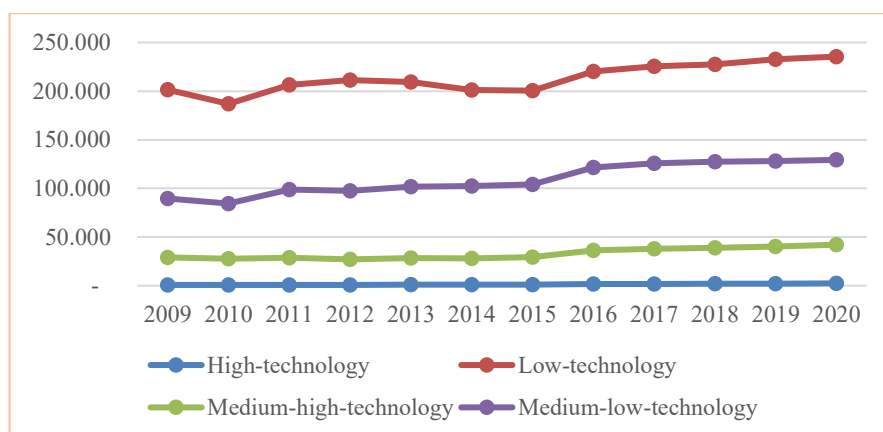
Code	Sectors	Technology Intensity
10	Manufacture of food products	Low-technology
11	Manufacture of beverages	Low-technology
12	Manufacture of tobacco products	Low-technology
13	Manufacture of textiles	Low-technology
14	Manufacture of wearing apparel	Low-technology
15	Manufacture of leather and related products	Low-technology
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Low-technology
17	Manufacture of paper and paper products	Low-technology
18	Printing and reproduction of recorded media	Low-technology
19	Manufacture of coke and refined petroleum products	Medium-low-technology
20	Manufacture of chemicals and chemical products	Medium-high-technology
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	High-technology
22	Manufacture of rubber and plastic products	Medium-low-technology
23	Manufacture of other non-metallic mineral products	Medium-low-technology
24	Manufacture of basic metals	Medium-low-technology
25	Manufacture of fabricated metal products, except machinery and equipment	Medium-low-technology
26	Manufacture of computer, electronic and optical products	High-technology
27	Manufacture of electrical equipment	Medium-high-technology
28	Manufacture of machinery and equipment n.e.c.	Medium-high-technology
29	Manufacture of motor vehicles, trailers and semi-trailers	Medium-high-technology
30	Manufacture of other transport equipment	Medium-high-technology
31	Manufacture of furniture	Low-technology
32	Other manufacturing	Low-technology
33	Repair and installation of machinery and equipment	Medium-low-technology

Source: Eurostat

2.4.2. Enterprises and Employment

The previous chapter mentioned about the manufacturing industry's ability to create labor and entrepreneurship as its long-standing strength. But, the sectors where these resources are directed matter in understanding the industry's resource allocation. The distribution of the number of enterprises in the manufacturing industry sub-sectors by the technology intensity by years is shown in Figure 2.9. The technological intensity composition of the enterprises has not changed significantly in the last 12 years, the weight and ranking of the categories remained more or less the same. More than half of the enterprises operate in low-technology sectors and One-third of the enterprises exist in medium-low-technology sectors. Although the number of enterprises in high-technology sectors increased significantly, nearly tripling from 797 in 2009 to 2,420 in 2020, it still has not reached sufficient volume. The number of enterprises in medium-high-technology sectors, 28,990 in 2009, increased to 42,146 in 2020. The number of enterprises in medium-low-technology sectors increased from 89,506 in 2009 to 129,393 in 2020. The number of enterprises in low-technology sectors that constitute the majority of the manufacturing industry increased from 201,552 in 2009 to 235,536 in 2020. The first four sub-sectors with the highest number of enterprises as of 2020 are as follows: fabricated metal products, except machinery and equipment, wearing apparel, food products, and furniture sectors.

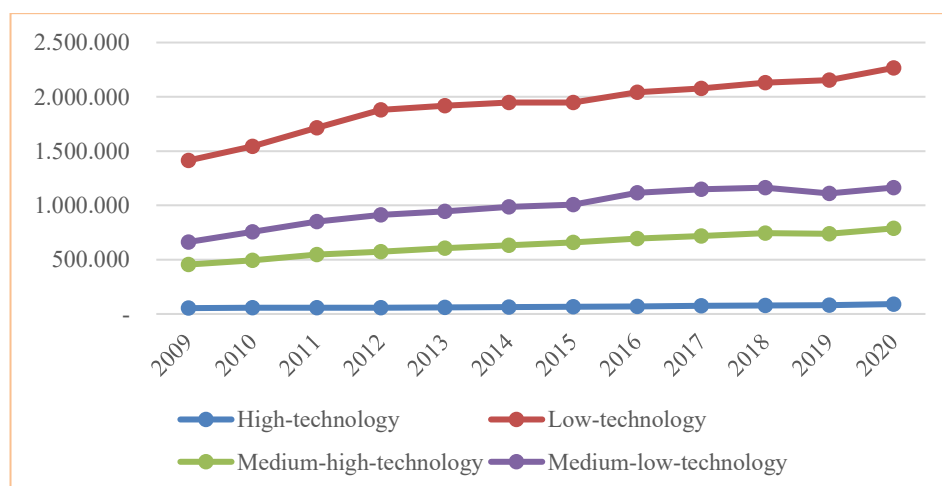
Figure 2.9. Number of Enterprises in Manufacturing Industry by Technology Intensity (2009-2020).



Source: Turkstat

The volume of the labor force employed by the manufacturing industry sub-sectors is shown in Figure 2.10. The distribution of employees by technology intensity largely overlaps with the distribution of enterprises. A difference for medium-high-technology sectors is that its share in the number of employees is slightly higher than its share in enterprises. Employees predominantly work in low-technology sectors. High-technology sectors have a very low share in the number of employees as in the number of enterprises. However, in 2020, high-technology sector accounts for 6 per thousand of the number of enterprises, its weight in the number of employees corresponds to 2%. The number of employees in high-technology sectors, 53,681 in 2009, increased to 91,009 in 2020. The number of employees in medium-high-technology sectors grew from 454,954 to 788,078. The number of employees in medium-low-technology intensive sectors grew from 662,502 to 1,164,207. Low-technology sectors, which employ most of the workers in the manufacturing industry, increased its employment from 1,413,636 to 2,265,688. The top three sub-sectors employing the largest number of employees take part in low-technology sectors. These are wearing apparel, food products, and textile sectors, all of which account for 39% of the employment.

Figure 2.10. Number of Employees in Manufacturing Industry by Technology Intensity (2009-2020).



Source: Turkstat

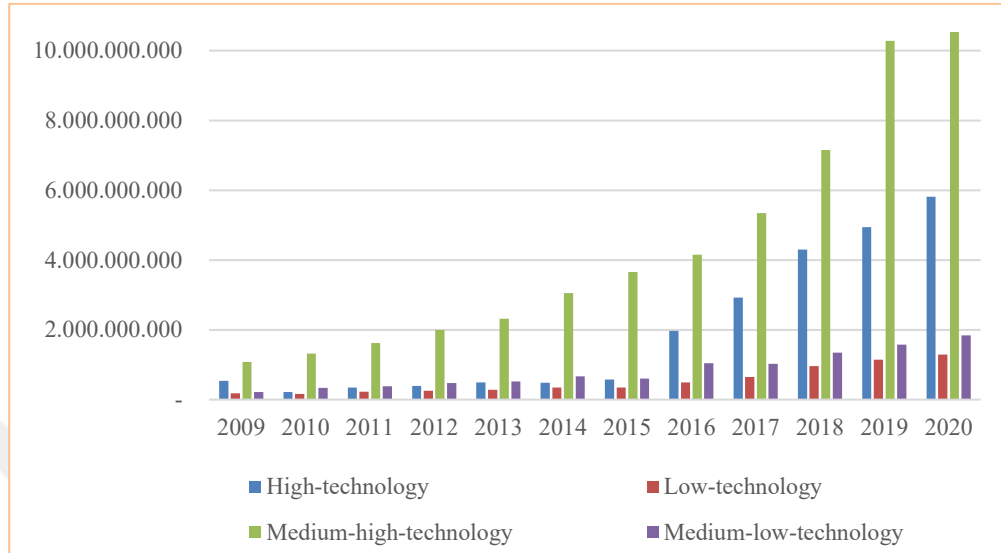
2.4.3. Research and Development Activities

The manufacturing industry is a critical part of an innovation ecosystem as it transforms ideas and knowledge into tangible and usable products. When newly produced knowledge and idea becomes a commercialized product, it brings profit to the firms and increases their market share. The basis for increasing production and maintaining competitive advantage in trade lies in allocating more resources to innovation and R&D. On the other hand, the industry's approach to innovation must be understood to initiate solid and effective policies to accelerate the technological transformation of firms and industries. In this respect, R&D expenditures and R&D human capital will be reviewed in the following sections to explore the current R&D outlook of the sectors.

Figure 2.11. summarizes R&D expenditure of the manufacturing industry sub-sectors according to their technology intensity. As can be seen, medium-high-technology and high-technology sectors come to the fore in R&D expenditure. From 2009 to 2020, they increased R&D spending significantly. While medium-high-technology sectors regularly increased their R&D expenditure, high-technology sectors managed to make a significant leap in 2016, nearly three and a half times higher than the previous year. Low-technology and medium-low-technology sectors did not prefer to spend much on R&D.

R&D expenditures have not evenly distributed among sub-sectors. The top five sub-sectors that made the highest spending constitute 75% of all expenditures. The top five sub-sectors in R&D spending resides in medium-high-technology and high-technology categories and are listed as follows: computer, electronic and optical products, electrical equipment, machinery and equipment n.e.c., motor vehicles, trailers and semi-trailers, and other transport equipment sectors. Among low-technology sectors, which made the least R&D expenditures, textile and food products sectors differ positively from the others within their own category.

Figure 2.11. R&D Expenditure of Manufacturing Industry by Technology Intensity (2009-2020).



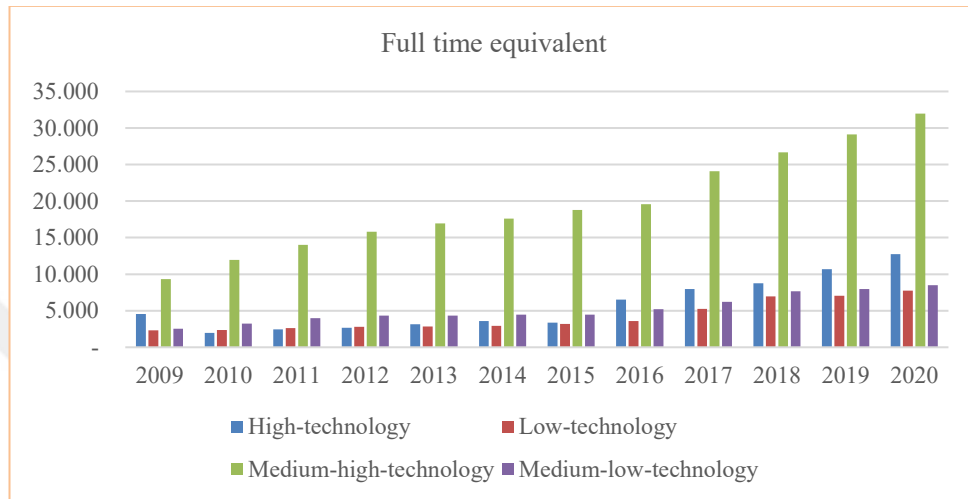
Source: Turkstat

The number of personnel allocated to R&D is another important innovation indicator showing the role of human capital in technology and knowledge production. We can see the full-time equivalent number of R&D personnel employed in the manufacturing industry sub-sectors by technology intensity in Figure 2.12. Most of the R&D personnel are employed by medium-high-technology sectors with 52%. The second position belongs to high-technology sectors with 21%. The remaining R&D personnel is distributed evenly between medium-low-technology and low-technology sectors. The increasing trend in the number of R&D personnel in high-technology and medium-high-technology sectors can be considered a promising situation for the future of manufacturing industry.

The data on the number of R&D personnel show that the top five sub-sectors, as mentioned earlier in the R&D expenditure passage, allocate the most budget for R&D expenditure also stand out as the sectors that employ the most R&D personnel. It is sensible to touch upon the number of R&D personnel in low-technology and medium-low-technology sectors. Textiles and food production sectors in low-technology category and rubber and plastic products, fabricated metal products,

except machinery and equipment sector in medium-low-technology category differ positively in terms of the number of R&D personnel within their own category.

Figure 2.12. Number of R&D Personnel in Manufacturing Industry by Technology Intensity (2009-2020).

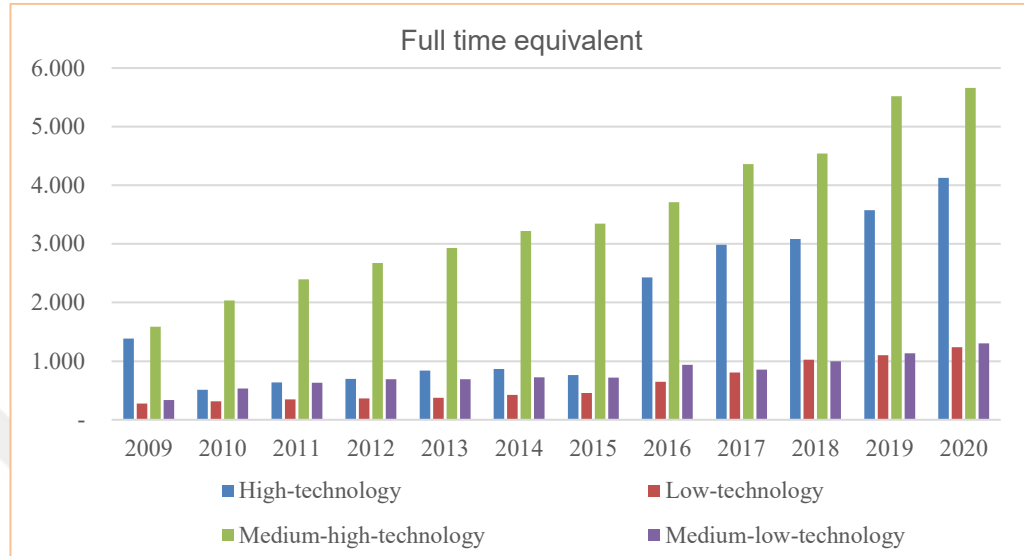


Source: Turkstat

It is sensible to present the number of Ph.D. and master's degree R&D personnel to see the skill acquisition in the manufacturing industry sub-sectors. Figure 2.13. shows the employment of highly trained R&D workers.

The total number of Ph.D. and master's degree R&D personnel was 3,590 in 2009, grew significantly and uninterruptedly, and reached 12,330 in 2020. As of 2020, many Ph. D and master's degree R&D personnel were employed in high-technology sectors and medium-high-technology sectors. The distribution of Ph.D. and master's degree R&D personnel to sectors is: 46% in medium-high-technology sectors, %34 in the high-technology sector, %10 medium-low-technology sector, and %10 low-technology sectors. As of 2020, the first sub-sector that employs the highest number of Ph.D. and master's degree R&D personnel is computer, electronic and optical products sector with 3,566 full-time equivalent personnel. The second is other transport equipment sector that employs 1,508 Ph.D. and master's degree R&D personnel. The third is motor vehicles, trailers and semi-trailers sector that employs 1,489 Ph.D. and master's degree R&D personnel. The fourth place belongs to electrical equipment sector that employs 1,144.

Figure 2.13. Number of Ph.D. and Master's Degree R&D Personnel in Manufacturing Industry by Technology Intensity (2009-2020).



Source: Turkstat

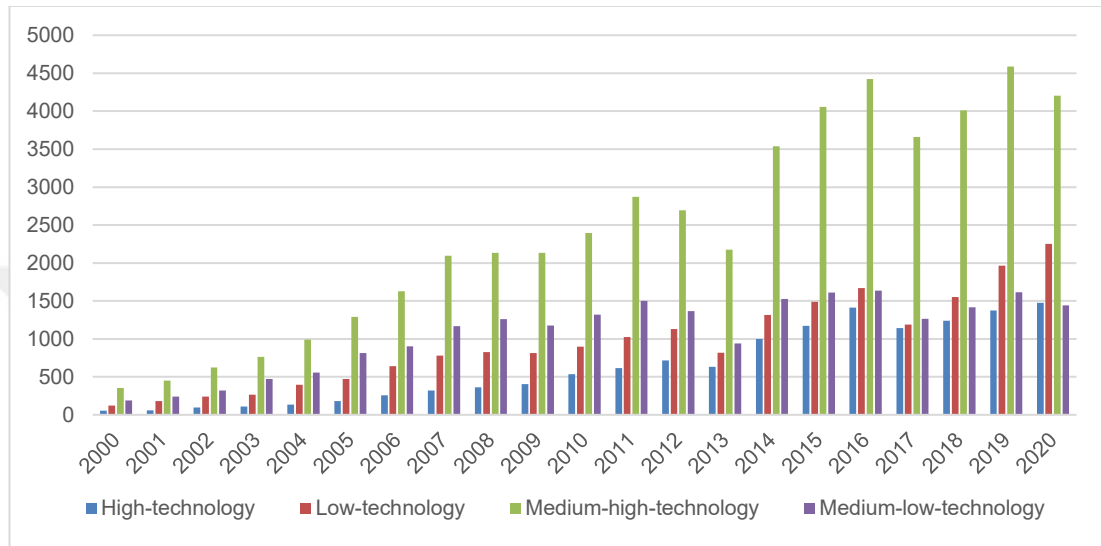
2.4.4. Patent Activities

The protection of intellectual property rights has an important place in the commercialization of products resulting from R&D and innovation. It functions to preserve monopoly power for a certain period. Contrary to R&D activities, the number of patents is an outcome indicator that reflects the innovation capacity of an economy. There has been a huge increase in patent applications starting from the mid-2000s. In 2000, there were 277 domestic patent applications and 23 domestic patent registrations to the Turkish Patent and Trademark Office. In 2020, the number of domestic patent applications was 8,200 and the number of domestic patent registrations was 2,214.

The data in Figure 2.14. regarding patent and utility model applications was published by the Turkish Patent and Trademark Office (TURKPATENT) in accordance with the Nace Rev.1.1 classification system. We determined the sectors and technology intensity of the applicants in the table published by TURKPATENT, classified and presented them accordingly in the Figure below. The number of patent and utility model applications, 720 in 2000, increased to 9,375 in 2020, making a big jump. Medium-high-technology sectors made 48% of the applications. The

remaining share is as follows: 21% of the applications were from medium-low-technology, 19% from low-technology, and 12% from high-technology sectors.

Figure 2.14. Number of Domestic Patent and Utility Model Applications in Manufacturing Industry by Technology Intensity (2000-2020).



Source: Turkish Patent and Trademark Office

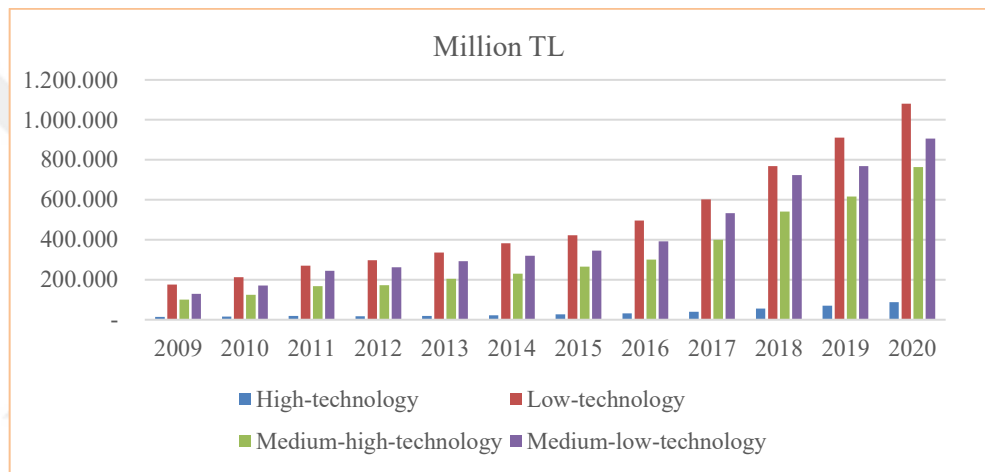
2.4.5. Production and Value-Added

Figure 2.15. summarizes the production value of the manufacturing industry sub-sectors over the years according to their technology intensity. The distribution of production value among sub-sectors has remained almost the same in the last decade. Between 2009 and 2020, the share of high-technology sectors in production value remained very low and was 3%. Low-technology sectors have the largest share with 39%. Then, medium-low-technology sectors with 33% and medium-high-technology sectors with 25% follow. Among the sub-sectors, those that stand out with their production value are: food products, textiles, basic metals and motor vehicles, trailers, and semi-trailers sectors. These four sectors meet 43% of the total production.

Figure 2.16. shows the amount of value-added at factor cost in the manufacturing industry sub-sectors. The distribution of the value-added produced by the sub-sectors displayed a stable image throughout the 2009-2020 period without

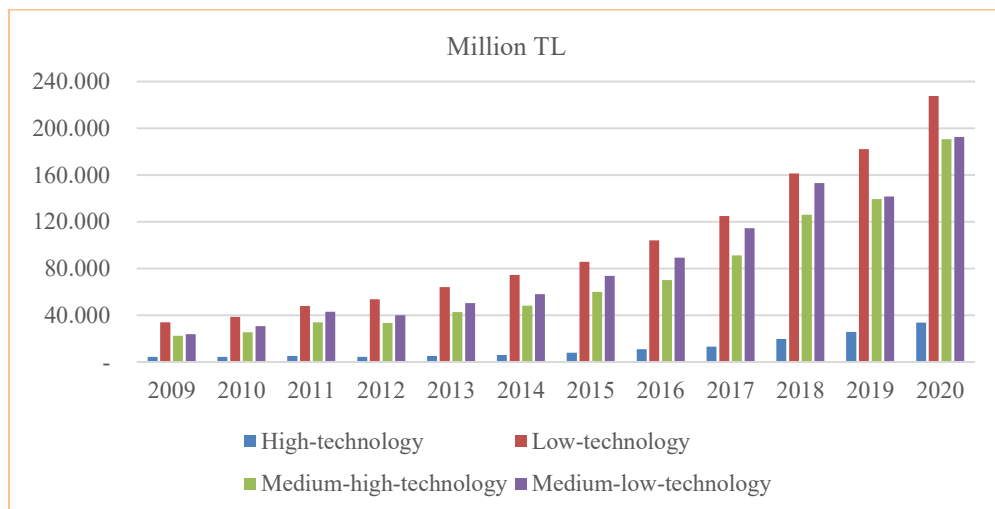
any significant change. The value-added proportions of the sub-sectors are as follows: low-technology sectors with 37%, medium-low-technology sectors with 31%, medium-high-technology sectors with 27%, and high-technology sectors only with 5%. As in the production value mentioned above, food products, textiles, basic metals and motor vehicles, trailers and semi-trailers sectors are again at the forefront with a 37% contribution to the amount of value-added.

Figure 2.15. Production in Manufacturing Industry by Technology Intensity (2009-2020).



Source: Turkstat

Figure 2.16. Value-Added in Manufacturing Industry by Technology Intensity (2009-2020).



Source: Turkstat

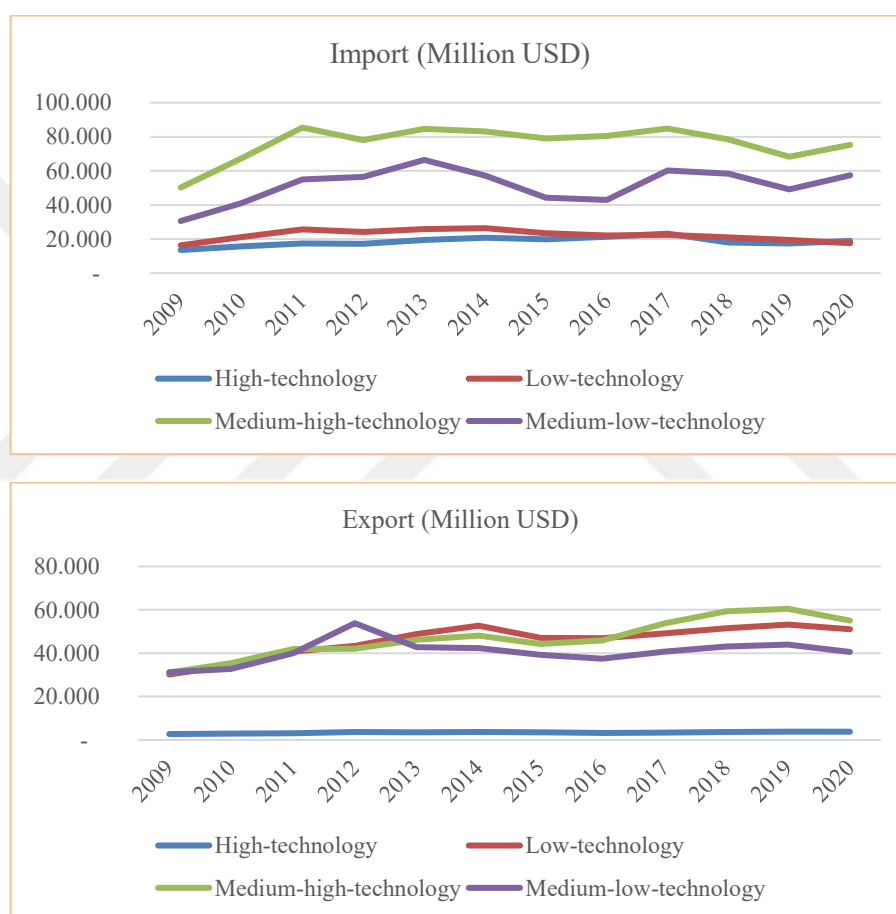
Rather than evaluating the output performance of the manufacturing industry sub-sectors only through production and value-added, and for comparison between sectors, the ratio of value-added to production was calculated. The highest value-added/production ratio was achieved by high-technology sectors with an average of 33%, corresponding to 38% in 2020. However, the value-added/production ratios of the other three categories were close to each other. Medium-high-technology sectors reached an average of 23%, medium-low-technology sectors reached an average of 20% and low-technology sectors reached an average of 20% during 2009-2020. The most successful sub-sectors for this indicator are: basic pharmaceutical products and pharmaceutical preparations sector has the highest ratio by %37. The second place is occupied by other transport equipment sector by %34. Repair and installation of machinery and equipment sector has 31%, computer, electronic and optical products sector has 30%, both machinery and equipment n.e.c. and other non-metallic mineral products sector has 27% value-added/production ratio.

2.4.6. Export and Import

Import and export are critical indicators that show which technology-intensive sectors in the manufacturing industry have gained a competitive advantage in global trade. The manufacturing industry, the major determinant sector of the foreign trade volume of the Turkish economy, had a surplus in 2019 and became more competitive compared to previous years. High-technology and medium-high-technology sectors are considered knowledge-intensive sectors. In export, the share of high-technology sectors, which is a key performance indicator of a knowledge-intensive economy, remained at 3% for the 2009-2020 period. The export of high-technology sectors rose from 2,742 million USD in 2009 to 3,817 million USD in 2020, increasing by 39%. Unfortunately, the export growth rate and export volume of high-technology sectors in 2009-2020 were insufficient. Medium-high-technology, medium-low-technology, and low-technology sectors showed close export performance, accounting for 34%, 30%, and 33% of total manufacturing industry exports, respectively. Medium-high-technology sectors reached the highest export performance in the manufacturing industry with a remarkable and increasing

performance, holding a slightly leading position. This success mostly stems from the contributions of Motor vehicles, trailers and semi-trailer, Electrical equipment, Machinery and equipment n.e.c. and Chemical and chemical products sectors. The most successful sectors in export throughout 2009-2020; motor vehicles, trailer and semi-trailers, basic metals and wearing apparel sector with 38% share.

Figure 2.17. Export and Import of Manufacturing Industry by Technology Intensity (2009-2020).



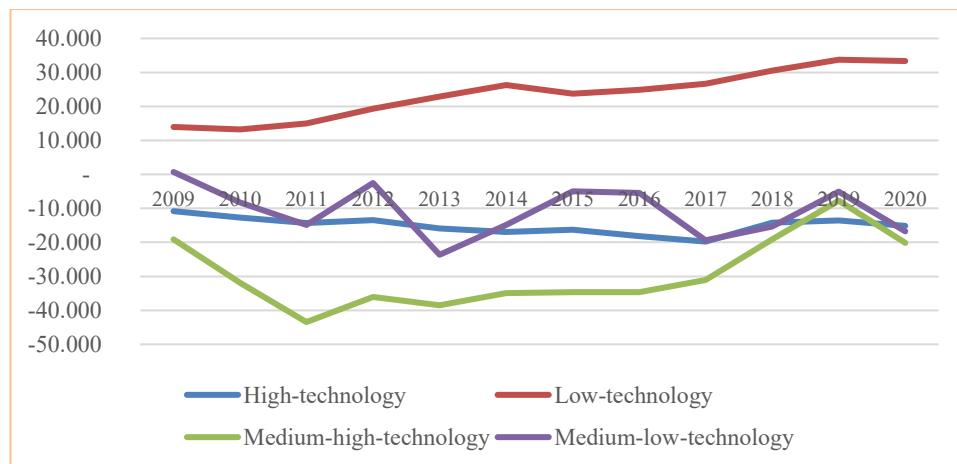
Source: Turkstat

On the import side, medium-high-technology sectors are the most dominant and account for 45% of the manufacturing industry's total imports. Second, medium-low-technology sectors come with a 31% share. The categories with the smallest share in imports are low-technology and high-technology sectors with 13% and 11%, respectively. Import has been concentrated around specific sectors. The top-down list of six sectors that constitute 69% of imports is: basic metals, chemicals and chemical

products, machinery and equipment n.e.c., motor vehicles, trailers and semi-trailers, coke and refined petroleum products, and computer, electronic and optical products sectors.

The foreign trade balance of the manufacturing industry sub-sectors is shown in Figure 2.18. The only category with a surplus in the foreign trade balance is low-technology sectors that gave a continuous and increasing surplus in the 2009-2020 period. In all other technology categories, our economy had deficits in every year, except for medium-low-technology sectors only in 2009. High-technology sectors continued to have an increasing deficit until the last three years. The deficits of medium-low-technology sectors fluctuated constantly. Medium-high-technology sectors continued to have a deficit in decreasing amounts from 2011 to 2019 thanks to the high export performance in recent years. Between 2009 and 2020, twelve sub-sectors had a foreign trade surplus, and eleven sub-sectors had a foreign trade deficit. The three sub-sectors that make up 64% of the foreign trade surplus are: wearing apparel, textiles, and food products sectors. The five sub-sectors that make up 87% of the foreign trade deficit are as follows: chemicals and chemical products, computer, electronic and optical products, machinery and equipment n.e.c., coke and refined petroleum products, and basic metals sectors.

Figure 2.18. Foreign Trade Balance of Manufacturing Industry by Technology Intensity (2009-2020).



Source: Turkstat

2.4.7. General Overview of the Section

This section provides an overview of the current technological situation of the manufacturing industry through some key indicators and innovation indicators. The sectors were grouped according to their technology intensities and interpreted accordingly. This gives a better understanding of which technology-intensive sectors the manufacturing industry allocates its resources and where innovative activities are concentrated. After reviewing the resource distribution, we intended to discover the industry's foreign trade, production, and value-added over the perspective of sectoral technology intensity.

A concentration was detected around low-technology sectors regarding labor resource allocation and entrepreneurial activities. The dominance of these sectors in resource utilization also manifests itself in the outputs. Low-technology and medium-low-technology sectors meet more than two-thirds of total production and value-added. On the other hand, high-technology sectors, which have a very low share of approximately 3% in total production and value-added, are the most efficient sector regarding the value added to production ratio. Medium-high-technology sectors hold promise to increase output in the future considering their performance, which corresponds to a quarter of total production and value-added in the last twelve years.

Medium-high-technology and medium-low-technology sectors account for three-quarters of import volume. Unfortunately, the share of high-technology sectors in export, which can be considered a critical indicator, occupied a small proportion with 3%. Medium-high-technology sectors have reached a promising export volume of 34%. To draw an inference, the high demand for medium technology goods can be interpreted as an indicator of the desire for development and efficiency in the economy and the strong demand for technology use.

For innovative indicators, medium-high-technology sectors are at the center of R&D expenditures, followed by high-technology sectors, as expected. Medium-high-technology sectors are also way ahead of other sectors in terms of the number of R&D personnel and the number of patents and utility model applications. High-

technology sectors, which rank second in the employment of Ph.D. and master's degree R&D personnel, draw attention to the demand for highly trained workers. Low-technology and medium-low-technology sectors do not prefer to allocate the necessary resources for R&D. However, they are in a relatively good position in patent applications.

We can also make general inferences from the information presented in this section. The structure of the manufacturing industry does not seem to go towards a period dominated by high-technology sectors. However, most of the resources are transferred to low-technology sectors. There is a dependency on high-technology-intensive goods as production input, as can be inferred from the high share of medium-high-technology sectors in the industry's imports. The special status of medium-high-technology sectors in production, value-added, export, and innovative activities is of great importance. Medium-high-technology sectors are possibly best suited to a central role in technological progress and innovation in the Turkish manufacturing industry.

CHAPTER THREE

AN EMPIRICAL ANALYSIS: THE IMPACT OF INNOVATION ON PRODUCTION AND EXPORT IN THE TURKISH MANUFACTURING INDUSTRY

3.1. Introduction

In recent decades, Turkish manufacturing firms have started allocating more resources to catch technological change and increased their R&D activities in terms of R&D investment and R&D personnel to promote their production and export performance. When we check over the expenditures for the research period in particular. We notice that the manufacturing industry constituted a significant part of the total R&D expenditures as of 2020, with 37%, while 24% in 2009. This rapid growth corresponds to a 10-fold increase in the manufacturing industry's total amount of R&D expenditures in the same period. Testing the effectiveness of this remarkable rise has emerged as the primary motivation for conducting this research.

We considered two different measures to represent innovative activities in the Turkish manufacturing industry sub-sectors. R&D expenditure is the primary variable we employed in the empirical part of this research. However, the number of R&D personnel can also be used as an alternative innovation indicator. We present the regression results in which the number of R&D personnel is taken as a proxy of innovation in the appendix of this thesis.

In this chapter, the impact of research and development activities on the production and export performance of the Turkish manufacturing industry will be tested empirically. The research was carried out using two different econometric equations: the production function and the export demand function, based on the data from 22 manufacturing industry sub-sectors covering the period 2009-2020. The sub-sectors included in the study are shown in table 2.7 in the previous chapter. 12-Manufacture of tobacco products and 33-Repair and installation of machinery and

equipment sectors are excluded due to the unavailability of the data for some variables.

The rest of this chapter is as follows. The first section defines regression models of the study, dependent and explanatory variables, and the descriptive statistics of the data. The second section briefly presents the theoretical framework of panel data estimation methods, unit root tests, model selection tests, and diagnostic tests used in the empirical analysis. The third section contains the findings of the empirical analysis.

3.2. Empirical Models, Variables and Data

As stated in theory, technological knowledge gained through R&D and innovation is considered the leading factor of economic growth. To this end, two separate equations are constructed to measure the impact of R&D on the production and exports of the Turkish manufacturing industry.

Models and Variables:

1) Production Model

First, we consider the production function equation (3.1) to estimate manufacturing industry's production. In addition to capital and labor, we added R&D expenditure as an explanatory variable to the production function. In theory, capital and labor are expected to expand output. R&D expenditure, which represent innovation, are also expected to contribute to the firm's production and thus to sectoral production.

$$\ln PROD_{it} = \beta_0 + \beta_1 \ln CPT_{it} + \beta_2 \ln LBR_{it} + \beta_3 \ln RDEX_{it} + \varepsilon_{it} \quad (3.1)$$

where $i=1,2,\dots,22$ $t=1,2,\dots,12$

InPROD (Production): Sectoral production, which is the dependent variable of the production model, is generated from the Annual Industry and Service Statistics published by Turkstat and expressed in logarithmic form. The nominal production value is the monetary value of the amount produced by the units, based on sales,

including changes in stocks and the resale of goods (Turkstat, Annual Industry and Service Statistics). The nominal production value is deflated by each sector's domestic producer prices.

InCPT (Capital): Capital is the most fundamental production tool as stated in the production theory. Since the data on sectoral capital value is not available, tangible fixed assets value in the manufacturing industries sectoral balance sheets published by the CBRT is taken as a proxy of the capital and expressed in logarithmic form. The tangible fixed assets values are deflated by each sector's domestic producer prices.

InLBR (Labor): The amount of labor is yet another main input for production. The number of persons employed in the manufacturing industry sub-sectors is taken for this variable and expressed in logarithmic form. The data is published by Turkstat in the Annual Industry and Service Statistics.

InRDEX (R&D Expenditure): R&D expenditures made by the manufacturing industry sub-sectors are taken from the Research and Development Activities Survey published by Turkstat and used as a proxy for innovative activities. To obtain real R&D expenditure, we generated a new price index, weighting the domestic producer price indices of two high-technology sectors (each weighted at %25) and five medium-high-technology sectors (each weighted at %10). The values of R&D expenditure were deflated using this new price index for each sector and expressed in logarithmic form.

2) Export Demand Model

Second, the export demand equation was estimated for the manufacturing industry. The export demand equation (3.2) is the function of foreign income and relative prices. We also added R&D expenditure as the control variable to this function. An increase in foreign income will stimulate demand for the exporting goods. A decrease in the relative prices of the exporting country will positively affect its export quantity. We expect R&D expenditures to contribute to firms' exports by

extending their production competence, competitiveness, and product development capacity.

$$\ln EXPT_{it} = \beta_0 + \beta_4 \ln INC_t + \beta_5 \ln PRC_{it} + \beta_6 \ln RDEX_{it} + \varepsilon_{it} \quad (3.2)$$

where $i=1,2,\dots,22$ $t=1,2,\dots,12$

InEXPT (Export): The amount of sectoral export calculated according to the special trade system method by Turkstat is utilized as the dependent variable of the export demand model and expressed in logarithmic form. First, the export amount is converted into Turkish Lira using the annual average USD buying exchange rate of The Central Bank of the Republic of Turkey (CBRT). Then, the export amount is deflated by each sector's non-domestic producer prices. The data sources used in this calculation are shown in Table 3.1.

InPRC (Relative Prices): The real effective exchange rate (REER) for each sub-sector is calculated using the formula below (3.3) (Sektörel Reel Efektif Döviz Kurları: Türkiye Uygulaması, 2012, p.10), which indicates the relative prices for each sub-sector. In the calculation, the manufacturing industry total output price indices of 24 European countries (P_{ji} foreign country), which corresponds to 47% of Turkey's exports, and the Turkish manufacturing industry non-domestic producer prices (P_j turkey) were used. The European Union-28 price index of the sub-sector is used for countries where Eurostat did not publish a price index for the relevant sub-sector. The average buying exchange rates published by the CBRT for each country's currency is used as *the exchange rate*. The weight of each country (*foreign country's weight in export*) in the total exports of Turkey to 24 European countries was calculated as the country weight. In the formula, j denotes sectors, i denotes countries, n denotes the number of countries. The sources of the data used in the calculation of the REER are shown in Table 3.1. The values is expressed in logarithmic form.

$$REER_j = \prod_{i=1}^n \left[\frac{P_j \text{ turkey}}{P_{ji} \text{ foreign country} * \text{exchange rate } i} \right]^{\text{foreign country's weight in export}} \quad (3.3)$$

InINC (Foreign Income): Foreign income is the weighted sum of the GDP of 27 trade partners of Turkey, which constitute 75% of Turkey's exports for the 2009-2020 period. GDP values, published by the World Bank, were converted into Turkish Lira with the CBRT's average USD buying exchange rate. Then the real value is calculated using the World Bank GDP deflator. The total foreign income value for each year was calculated by weighting the 27 countries in proportion to their share in Turkey's exports. The sources of the data used in the calculation of foreign income are shown in Table 3.1.

InRDEX (R&D Expenditure): The calculation of this variable is described above in the production model.

Alternative Variable for Innovation:

The Number of R&D Personnel (InRDLB) is an alternative proxy that can be used to represent innovative activities in the Turkish manufacturing industry sub-sectors. The data is obtained from the Research and Development Activities Survey published by Turkstat. The full-time equivalent value of the number of R&D personnel employed in the manufacturing industry sub-sectors is used and expressed in logarithmic form.

As correlation matrix table shows a significant correlation between R&D expenditure (*InRDEX*) and the number of R&D personnel (*InRDLB*), we preferred to use R&D expenditure as the primary innovation indicator in the production and export demand models. On the other hand, the regression results, in which we used the number of R&D personnel as an alternative proxy for innovation, are presented in the appendix of this thesis.

Data:

The data of the variables related to the models (3.1) and (3.2) were obtained from different sources such as Turkstat, The CBRT, Eurostat, and the World Bank over the period 2009-2020. Since the foreign income did not show a sectoral variation, the values of this variable are the same for all sub-sectors. Except for foreign income, two-digit sub-sector data for the manufacturing industry is available

for all other variables. There are no missing data for any year or sub-sector. The data set reflects balanced panel data characteristics.

All the variables explained above were indexed based on 2009 (2009=100). Following the indexation, these values were transformed into natural logarithmic form and used in the analysis. The sources from which the data were collected are described below.

Table 3.1. The Sources of Data.

Data	Source
Export (USD)	Turkstat (Foreign Trade Statistics)
Domestic Producer Price Index	Turkstat
Non-Domestic Producer Price Index	Turkstat
R&D Expenditure	Turkstat (Research and Development Activities Survey)
Number of R&D Personnel	Turkstat (Research and Development Activities Survey)
Production Value	Turkstat (Annual Industry and Service Statistics)
Number of Personnel Employed	Turkstat (Annual Industry and Service Statistics)
World GDP (Current USD)	The World Bank
World GDP Deflator	The World Bank
Total Output Price Index (National Currency)	Eurostat (Producer Prices in Industry)
Annual Average Exchange Rates	The Central Bank of the Republic of Turkey (Indicative Exchange Rates)
Tangible Fixed Assets	The Central Bank of the Republic of Turkey (Company Accounts)

Table 3.2. shows the descriptive statistics of the variables used in the empirical models. In the table below, the statistical characteristics of the data set are summarized in detail. Descriptive statistics are broken down into measures of central tendency and measures of variability. Measures of central tendency include the mean and median, while measures of variability include standard deviation, minimum and maximum, kurtosis, and skewness. Jargue bera is a statistic that measures the deviation from the normal distribution.

Table 3.2. Descriptive Statistics of The Variables

Sample: 2009-2020								
	<i>lnPROD</i>	<i>lnEXPT</i>	<i>lnLBR</i>	<i>lnCPT</i>	<i>lnINC</i>	<i>lnPRC</i>	<i>lnRDEX</i>	<i>lnRDLB</i>
Mean	5,04	5,05	4,87	4,91	5,23	4,61	5,25	5,13
Median	5,03	5,08	4,88	4,87	5,12	4,61	5,27	5,11
Maximum	6,00	6,23	5,30	6,18	6,18	4,90	6,74	6,55
Minimum	4,32	4,23	4,43	4,11	4,59	4,27	3,33	3,55
Std. Dev.	0,31	0,35	0,18	0,32	0,53	0,11	0,58	0,58
Skewness	0,16	0,44	-0,12	0,95	0,47	-0,26	-0,03	-0,06
Kurtosis	2,96	3,22	2,14	4,94	1,87	3,21	3,17	2,70
Jarque-Bera	1,19	9,45	8,74	81,62	23,99	3,69	0,38	1,14
Probability	0,55	0,00	0,01	0,00	0,00	0,15	0,82	0,56
Observ.	264	264	264	264	264	264	264	264

Table 3.3. shows the correlation matrix of the variables. Each value in the table shows the correlation between the two variables. This table enables us to determine whether there is a strong linear correlation between the variables. The correlation coefficient can take a value between -1 and 1, and the farther it is from zero, the stronger the relationship between the two variables. 0 indicates no linear correlation.

Table 3.3. Correlation Matrix of The Variables

	<i>lnPROD</i>	<i>lnEXPT</i>	<i>lnCPT</i>	<i>lnLBR</i>	<i>lnINC</i>	<i>lnPRC</i>	<i>lnRDEX</i>	<i>lnRDLB</i>
<i>lnPROD</i>	1							
<i>lnEXPT</i>	0,395	1						
<i>lnCPT</i>	0,402	0,499	1					
<i>lnLBR</i>	0,689	0,464	0,379	1				
<i>lnINC</i>	0,646	0,611	0,466	0,638	1			
<i>lnPRC</i>	-0,139	-0,264	-0,199	-0,034	-0,058	1		
<i>lnRDEX</i>	0,528	0,396	0,320	0,501	0,625	-0,047	1	
<i>lnRDLB</i>	0,375	0,312	0,208	0,444	0,600	0,077	0,858	1

3.3. Methodology of Empirical Analysis

This study estimates the impact of R&D expenditures on sectoral production and export using panel data analysis methodology via the production equation (3.1) and the export demand equation (3.2). This section will provide a brief explanation on the panel data methodology. Unit root test, pooled effect, fixed effect, and random effect estimation methods, model selection tests, and diagnostic tests are the subtitles covered in this part.

3.3.1. Panel Unit Root Test

Unit root tests examine the stationarity of variables. The mean, variance, and autocovariance of the variables are supposed to be around the expected value. These values have to be constant over time to obtain efficient estimates. In the case of non-stationarity, series are correlated with their past values. A spurious regression problem arises in this situation, and the regression results are considered misleading.

Levin Lin Chu-LLC (2002), Im, Pesaran, Shin-IPS (2003), Fisher ADF, and Philips Perron tests are known as the first generation panel unit root tests in the literature. In the LLC test, known as the homogeneous panel unit root test, assumes that all cross-section units in the panel have the same autoregressive parameter (ρ). In contrast, in the heterogeneous panel unit root tests such as IPS, ADF, PP, all cross-section units are assumed to have individual autoregressive parameters and unit root processes. In these tests, the null hypothesis states the variable contains a unit root, the alternative represents stationarity. Though the results of these tests will be presented on the following pages, LLC test results will be used in this study.

LLC proposes a stronger panel unit root test than individual unit root tests for each cross-section, arguing that individual unit root tests for each cross-section unit, have limited power against alternative hypotheses with highly persistent deviations from equilibrium, especially in small samples. It has a three-step procedure, first, performing ADF regression for each unit and lag order permitted to vary for each unit. Second, estimating the ratio of long-run to short-run standard deviations. Third, computing panel test statistics (Baltagi, 2021, p.340-342).

The LLC unit root model is presented below:

$$\Delta Y_{it} = \rho Y_{it-1} + \sum_{L=1}^P \theta_{iL} \Delta Y_{it-L} + \alpha_{mi} d_{mt} + \varepsilon_{it} \quad m=1,2,3 \quad (3.4)$$

Where d_{mt} corresponds to a deterministic variable, α_{mi} indicates vector of coefficients, L is used to determine optimal lag order.

$H_0: \rho=0$ (unit root)

$H_1: \rho \neq 0$ (stationarity)

According to Baltagi, “*The Monte Carlo simulations performed by LLC indicate that the normal distribution provides a good approximation to the empirical distribution of the test statistic even in relatively small samples and also that the panel unit root test provides dramatic improvements in power over separate unit root tests for each cross-section.*” (Baltagi, 2021, p.340-342).

Westerlund and Breitung, in their simulation study, asserted that the local power of the IPS test is always smaller than the local power of the LLC test. They also noted that the LLC test is uniformly more powerful than the IPS test (Westerlund and Breitung, 2009, p.9).

3.3.2. Panel Data Estimation Methods

Panel data refers to the collection of observations of variables over a given period (yearly, monthly, daily, etc.) for different cross-section units such as individuals, sectors, firms, states, regions, etc. Since our data covers 22 cross-section units and a 12-year time dimension, we can define it as micro panel data set. Utilizing panel data has some advantages and disadvantages: it gives more informative data, more degrees of freedom, more efficiency, and less collinearity among variables. Both differences and heterogeneity across units can be taken into account better. It is better to study the dynamics of change. The bias in parameter estimates can be reduced. Data collection problems, distortions of measurement error, cross-section dependence, and short time series dimensions are among the constraints of panel data.

This part briefly explains the three types of linear panel analysis methods most commonly used in applications. These methods are pooled, fixed effects, and random effects models.

The Pooled Estimation

First of all, we should question whether our data can be pooled or not. This model is also described as a restrictive panel data model since it assumes that there are no time or unit effects. It is also known as the classical model. In this method, the heterogeneity of panel data is ignored because of pooled regression procedure. The parameter estimates of intercept and slope coefficients remain fixed over time and across cross-section units.

The model is:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \varepsilon_{it} \quad i=1, 2, \dots, n \quad t=1, 2, \dots, t \quad (3.5)$$

Y stands for the dependent variable, X's stands for explanatory variables, i represents cross-sections units, t represents time dimension, and ε is the error term. Efficient and consistent β 's are estimated by the OLS (Ordinary Least Square) procedure under exogeneity ($E[u_{it}, X_{it}] = 0$), homoscedasticity, no autocorrelation, and no perfect multicollinearity (full rank) assumptions. The critical assumption of this method is exogeneity. It is hard to hold this assumption because it means that explanatory variables must capture the unit-specific attributes. Otherwise, the omitted variable problem will arise, resulting in biased regression estimates (Das, 2019, p.468-471).

The Fixed Effect Estimation

Unlike the classical model, we assume that each cross-section unit has a constant value (μ_i) that measures unobservable heterogeneity, which is treated as an estimated parameter (Tatoğlu, 2020, p.79). In other words, the differences between units are expressed by the differences in the intercept ($\beta_{0i} = \beta_0 + \mu_i$). That is how fixed effect model captures the differences between individuals

The fixed effect model is that:

$$Y_{it} = \beta_0 + \mu_i + \beta_1 X_{it} + \varepsilon_{it} \text{ (one-way model)} \quad (3.6)$$

$$Y_{it} = \beta_0 + \mu_i + \lambda_t + \beta_1 X_{it} + \varepsilon_{it} \text{ (two-way model)} \quad (3.7)$$

$$i=1, 2, \dots, n \quad t=1, 2, \dots, t$$

β_0 is constant, μ_i contains individual-specific effects, λ_t represents time-specific effects, and ε_{it} denotes the error term. The slope coefficients (β 's) are the same for all cross-sections. The fixed parameter (β_{0i}) is changing over cross-section units. While the model does not allow correlation between the explanatory variables (X_{it}) and the error term (ε_{it}), it allows correlation between X 's and unit effects (μ_i). No perfect multicollinearity, no autocorrelation, homoscedasticity are the other assumptions that provides efficiency to fixed effect model (Tatoğlu, 2020, p.80-89).

If the fixed effects model measures the unit effect, the intercept (β_{0i}) reflects the changes across units. However, if the model measures the time effect, the changes in the intercept (β_{0t}) will be due to time variation. Such models are called one-way fixed effects models. The models in which the intercept (β_{0it}) changes according to both units and time are defined as the two-way fixed effects model.

The Random Effect Estimation

The random effect model assumes a stochastic variation in the unobserved heterogeneity of cross-section units and treats the differences between units as a random variable. The model claims that these variations between cross-section units arise as a result of the sample selection process. Since the unit effect is not regarded as constant, it is due to a random effect. The model considers this randomness within the error term (V_{it}). With this feature, the random effects model is also called the error component model (ECM) (Tatoğlu, 2020, p.103-104).

Random effect model is:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + V_{it} \quad i=1, 2, \dots, n \quad t=1, 2, \dots, t \quad (3.8)$$

$$V_{it} = \varepsilon_{it} + \mu_i \text{ (one-way model)}$$

$$V_{it} = \varepsilon_{it} + \mu_i + \lambda_t \text{ (two-way model)}$$

μ_i represents unit errors or unit effects, λ_t represents time-specific error, ε_{it} represents remaining residual or idiosyncratic error. Strict exogeneity between explanatory variables and error terms ($E[X_i, \varepsilon_{it}] = 0$), no correlation between unit effects and explanatory variables ($E[X_i, \mu_i] = 0$), no perfect multicollinearity, no autocorrelation, homoscedasticity are the assumptions of the random effect model (Tatoğlu, 2020, p.105).

Similar to the fixed effect model, the one-way error component model captures either time-specific heterogeneity or cross section-specific heterogeneity by decomposing random error (V_{it}). The random error is decomposed in both time-specific and cross section-specific in the two-way random effect model (Das, 2019, p.471-472).

3.3.3. Model Selection Tests

The model selection in panel data analysis can be made according to some a priori evaluation. A researcher can opt for the fixed effects model if the cross-section units come from a non-random distribution such as country, region, or sector. On the other hand, random effects could be chosen if units are randomly selected from a large population (Tatoğlu, 2020, p.208). One can generally apply formal tests to determine the best-fitted estimation model among pooled, fixed effect, and random effect models. The F and LM test examine whether there are unit effects or time effects or both effects occur together. The Hausman test examines whether there is a correlation between unit effects and explanatory variables to decide between fixed effects and random effects.

F Test – Redundant Fixed Effect Test

The validity of the pooled model is examined against different models by applying the F test. The null hypothesis is tested using the homogenous parameters model (restricted) and the heterogenous parameters model (unrestricted). This test confirms that all observations are homogeneous. Otherwise there are unit effects and/or time effects (Tatoğlu, 2020, p.177).

$$H_0: \beta_{0i} = 0$$

$$H_1: \beta_{0i} \neq 0$$

Accepting the null hypothesis means that pooled model is applicable. The alternative hypothesis states that fixed effect must be applied.

Breusch Pagan LM Test

The BP LM test investigates the presence of individual heterogeneity. If it exists, the LM test recommends random effect model. If not, the validity of the classical pooled model is accepted. The null hypothesis states that the variance of the unit effects is zero (Tatoğlu, 2020, p.186).

$$H_0: \sigma_{\mu}^2 = 0$$

If the null hypothesis is accepted, the classical model is applicable. Otherwise, the random effect model is consistent.

Hausman Test

The Hausman test provides guidance in choosing the most appropriate method between random effect and fixed effect. There should be no correlation between unit effects and independent variables for the validity of random effects. The null hypothesis states that the unobserved individual effect is not correlated with any explanatory variable. The alternative hypothesis states there is correlation (Das, 2019, p.508).

$$H_0: E(\mu_{it} | X_{it}) = 0$$

$$H_1: E(\mu_{it} | X_{it}) \neq 0$$

If the null hypothesis is not rejected, the random effect is preferred. Otherwise, the alternative hypothesis that expresses the applicability of the fixed effect model is adopted.

3.3.4. Diagnostic Tests

After determining the appropriate analysis method, it should be tested whether there are any deviations from the assumptions that affect estimator's efficiency. In panel data models, error terms are assumed to have constant variance within and between units and uncorrelated with previous periods. If we estimate the model by ignoring the deviations from homoscedasticity and no autocorrelation assumptions, this will cause the parameter variances and thus the standard errors to be biased, reducing the efficiency. The reason for testing these assumptions is to understand if we need to compute robust and consistent estimators.

Heteroscedasticity

Heteroscedasticity is particularly encountered in cross-sectional data because of the variations associated with cross-section units. This variation triggers variations in error terms. Thus the homoscedastic variance assumption, which means all units have the same constant variance, is violated. This is a rather restrictive and challenging assumption for panels where the cross-section characteristics might differ significantly. Misspecification of the model, omitted variables, and outliers in the data can also be the origin of the problem. One way to detect the problem of heteroscedasticity can be done by observing the graph of the residual plot. The error terms are expected to be independently identically distributed (i.i.d) which implies homoscedasticity. In general, formal tests are used to detect heteroscedasticity. In case of the violation of the constant variance assumption, minimum variance property does not apply, variance of estimators becomes invalid and standard errors are considered incorrect. Consequently, standard t and F test statistics become unreliable under heteroscedasticity.

The conditional error variance in the case of heteroscedasticity is as follows:

$$E(\sigma_i^2 | X_i) = \sigma^2(x_i) = \sigma_i^2$$

Autocorrelation

Autocorrelation is a problem typically encountered in time series where we observe a natural sequence order in a period. It happens because the error terms are serially correlated with their lags.

The process of random error may be autoregressive (AR), moving average (MA), or both together (ARMA). The following random error equation follows the first-order AR(1) process. We assume $\rho=0$ for no autocorrelation (Das, 2019, p.126-128).

$$u_t = \rho u_{t-1} + v_t$$

$$E(u_i, u_j) = 0 \quad i \neq j$$

The assumption that there is no autocorrelation means that the error terms are independent of each other. This could be considered a restrictive assumption for time series data. The autocorrelation problem can be determined simply by examining the pattern of the residuals in a graph, or it can be detected using formal tests. In the case of autocorrelation, we underestimate the actual standard errors. However, estimators are still unbiased but not efficient. Since standard F and t-tests are no longer reliable, we obtain misleading results. We also come across highly significant coefficients and high R^2 values.

3.4. Findings of Empirical Analysis

This section presents the empirical results of the tests and regressions we used in our panel data analysis. We benefited from EViews 10 and Stata 16 econometric packages to obtain empirical results. First, we started with unit root tests. Since the panel data involves time series features, the unit root test of the variables must be applied to avoid spurious regression problems and get more reliable results. Then, we run our regression models based on the equations (3.1) and (3.2) using the pooled, fixed effects, and random effects methods. To select the best model, we utilized Breusch Pagan LM Test, Redundant Fixed Effect test, Hausman Test and provided

evaluations on the results of these model selection tests. Finally, we examined the diagnostic tests and used a robust estimation method to predict our equations.

3.4.1. Unit Root Test Results

Table 3.4 shows Levin, Lin, and Chu (LLC), Im, Pesaran, Shin (IPS), Augmented Dickey-Fuller (ADF), Philips Perron (PP) unit root test results. Unit root results at level $I(0)$ were obtained by choosing the Akaike Information Criterion (AIC) as lag length selection criteria. The results were calculated using max_lags:2 and the individual intercept options. We chose the Akaike Information Criterion (AIC) as the lag length selection criteria because it will be a better choice in smaller samples and give more accurate results according to Liew (2004) and Asghar and Abid (2007). The unit root statistics and the significance level of each statistic are demonstrated in the table below. Since foreign income (*lnINC*) variable data did not change according to the sub-sectors, it was not subjected to the unit root test. If the series contains a unit root, in other words, if they are non-stationary, they must be made stationary by taking the first difference to use them in the analysis.

Table 3.4. Unit Root Test Results.

Variables	LLC	IPS	ADF	PP
	$I(0)$	$I(0)$	$I(0)$	$I(0)$
<i>lnPROD</i>	- 6,45 ***	- 2,74 ***	76,17 ***	215,20 ***
<i>lnEXPT</i>	- 10,17 ***	- 3,88 ***	94,53 ***	150,23 ***
<i>lnLBR</i>	- 8,91 ***	- 4,65 ***	116,57 ***	196,95 ***
<i>lnCPT</i>	- 6,15 ***	- 1,15	62,06 **	92,91 ***
<i>lnPRC</i>	- 6,37 ***	- 5,19 ***	120,73 ***	147,32 ***
<i>lnRDEX</i>	- 3,85***	0,17	49,03	62,28 **
<i>lnRDLB</i>	-2,96***	0,82	54,75	69,96 ***
Individual Intercept, Lag length: Akaike Info Criterion, Max lags: 2 Significance levels: * $p<0.10$ ** $p<0.05$ *** $p<0.01$				

As mentioned earlier in the methodology section (p.104), according to Baltagi (2021) and Westerlund and Breitung (2009), the LLC test gives stronger results than the IPS in small samples. For this reason, we preferred to use the LLC unit root test

results. It proves that all variables are stationary at the level $I(0)$ at %1 significance level so that we can use them in the analysis with their original values.

3.4.2. Model Selection and Regression Results

We performed model selection tests to determine the best-fitted model between classical, fixed effects, and random effects models. These tests also indicate whether unit effect, time effect, or both effects exist together.

Table 3.5. presents model selection results for the production model. According to the Breusch Pagan LM Test, the null hypothesis for unit (cross-section) effects is rejected. However, the null hypothesis for the time effect is not rejected. These results show that the classical (pooled) model is not suitable and the one-way random effects model is applicable. In the Redundant Fixed Effect Test, since the statistical values for both unit and time effect are significant at 1% level, it suggests the validity of both unit effect and time effect, indicating that the two-way fixed effects model is applicable. Based on these results, we applied the Hausman Test to choose between the one-way random effects model and the two-way fixed effects model. Since the significance level of the Hausman Test statistic is above 5%, the null hypothesis is not rejected, suggesting that the random effects model is valid for our production model as the result of the formal model selection tests.

Table 3.5. Model Selection Tests Results of The Production Model.

Test	Cross Section	Period	Both
Breusch-Pagan LM Test	725,59 (0,00)	0,193 (0,65)	725,79 (0,00)
Redundant Fixed Effect Test (F Test)	35,56 (0,00)	3,43 (0,00)	26,24 (0,00)
Hausman Test (Chi-Square)	2,71 (0,43)		

The table below displays model selection results for the export demand model. According to the Breusch Pagan LM test, the null hypotheses for unit (cross-section) effects and time effects are significant at the 1% significance level. These results show that the use of the pooled model is not suitable and the two-way random effects model is applicable. As for the Redundant Fixed Effect Test, the cross-section effect is significant at the 1% level, meaning that the one-way fixed effect model is valid. Based on these results, we applied the Hausman Test to choose between the two-way random effects model and the one-way fixed effects model. Since the Hausman Test statistic is not significant, the null hypothesis is not rejected because its probability is greater than 5%. The random effects model is also valid for the export demand model.

Table 3.6. Model Selection Tests Results of The Export Demand Models

Test	Cross Section	Period	Both
Breusch-Pagan LM Test	530,05 (0,00)	17,10 (0,00)	547,15 (0,00)
Redundant Fixed Effect Test (F Test)	20,72 (0,00)		
Hausman Test (Chi-Square)	1,03 (0,79)		

Although the results of formal model selection tests suggest that the random effects estimator should be chosen for both the production and the export model. Based on some preliminary considerations, we can also decide which estimators are more suitable. If unobservable heterogeneity (μ_i) is considered as a predictable fixed parameter, the fixed effects model can be chosen. The random effects model can be selected, if it is a stochastic parameter. The fixed effect is appropriate if the cross-section units come from a non-random distribution such as country, region, or sector. The random effects could be chosen if units are randomly selected from a large population. On the other hand, even though the Hausman test recommends the random effects estimator, the fixed effects estimator is still consistent but less

efficient. Furthermore, some researchers prefer the fixed effects estimator, since they consider it is almost impossible to hold the assumption that the unit effects are uncorrelated with all explanatory variables, which is one of the assumptions of the random effect model (Tatoğlu, 2020, p.175-176). For this reason, the fixed effects estimator was chosen as the most suitable method for both the production and the export demand models, based on the information above.

Table 3.7. Regression Results of The Production Model.

Variables	Pooled Model (Coefficient- Prob.)	Fixed Effect (Coefficient- Prob.)	Random Effect (Coefficient- Prob.)
<i>lnCPT</i>	0,12 *** (0,005)	0,057 (0,143)	0,115 *** (0,002)
<i>lnLBR</i>	0,88 *** (0,000)	0,90 *** (0,000)	1,158 *** (0,000)
<i>lnRDEX</i>	0,11 *** (0,000)	0,038 * (0,062)	0,079 *** (0,001)
<i>Constant</i>	-0,53 (0,143)	0,14 (0,764)	-1,59 *** (0,000)
Observations	264	264	264
F statistics	99,65 (0,000)	59,08 (0,000)	361,45 (0,000)
R-squared	0,53	0,90	0,804
DW	0,136	0,410	0,445
Modified Wald test for groupwise heteroskedasticity chi2 (22) = 4721,50 , Prob>chi2 = 0.0000			
modified Bhargava et al. Baltagi-Wu LBI = 0.82261			
Significance levels: * p<0.10 ** p<0.05 *** p<0.01			

Table 3.7. shows three different regression results for our production equation: the pooled model, the two-way fixed effect model, the one-way random effect model. As stated above, we prefer the two-way fixed effects estimator for the production model, relying on some preliminary assessments. The results of the estimation produced by 264 observations for the period 2009-2020 indicate that

Labor (*lnLBR*) and R&D Expenditure (*lnRDEX*) are statistically significant explanatory variables on the amount of production. The signs of Labor and R&D expenditure variables are positive as expected. As for the diagnostic tests, DW and Baltagi-Wu statistics are considerably lower than 2, indicating the presence of autocorrelation. According to the modified Wald test result, the null hypothesis is rejected, showing a heteroscedasticity problem in the production model. Therefore, the fixed effect results are considered unbiased but not efficient. We need to predict the model with a robust and consistent estimator.

Table 3.8. Regression Results of The Export Demand Model.

Variables	Pooled Model (Coefficient- Prob.)	Fixed Effect (Coefficient- Prob.)	Random Effect (Coefficient- Prob.)
<i>lnINC</i>	0,39 *** (0,000)	0,35 *** (0,000)	0,35 *** (0,000)
<i>lnPRC</i>	- 0,73 *** (0,000)	- 0,48 *** (0,001)	- 0,52 *** (0,001)
<i>lnRDEX</i>	0,011 (0,75)	0,075 *** (0,014)	0,069 *** (0,021)
<i>Constant</i>	6,31 *** (0,000)	5,07 *** (0,000)	5,23 *** (0,000)
Observations	264	264	264
F statistics	64,35 (0,000)	38,99 (0,000)	154,38 (0,000)
R-squared	0,42	0,79	0,64
DW	0,285	0,79	0,72
Modified Wald test for groupwise heteroskedasticity chi2 (22) = 303.02 , Prob>chi2 = 0.0000			
modified Bhargava et al. Baltagi-Wu LBI = 1.12499			
Significance levels: * p<0.10 ** p<0.05 *** p<0.01			

The above table (Table 3.8.) shows three different regression results for our export model: the pooled model, the one-way fixed-effects model, the two-way random-effects model. As stated above, instead of using the results of model

selection tests, we preferred to use the two-way fixed effects model, considering some preliminary evaluations. The results of the estimation produced by 264 observations for the period 2009-2020 indicate that Foreign Income (*lnINC*), Relative Prices (*lnPRC*), and R&D Expenditure (*lnRDEX*) have a statistically significant effect on the amount of export. The signs of Foreign Income, R&D expenditure, and Relative Prices variables are positive as expected. As for the diagnostic tests, the Durbin Watson and Baltagi-Wu statistics show the existence of autocorrelation since their statistics are far from 2. Modified Wald test result indicates a heteroscedasticity problem in our export model. This means the test results are considered unbiased but not efficient. We need to estimate the model with a robust and consistent estimator.

3.4.3. Robust Estimation Results

As the diagnostic tests point out autocorrelation and heteroscedasticity problems, we need to employ consistent and robust estimators. Table 3.9. presents the fixed effect robust estimator results for both the production model and the export model. The probability values of the coefficients were calculated by obtaining the robust standard errors, which produce more reliable t values.

The production model confirms that capital (*lnCPT*) and labor (*lnLBR*) have a significant and positive effect on the production in the Turkish manufacturing industry in line with the theory, at 10% and 1% significance levels, respectively. When it comes to our innovation indicator, the contribution of R&D expenditure (*lnRDEX*) to the production is found significant at 1% significance level and positive as expected. The results show that a 1% increase in R&D expenditures increases the production by 0.038% in the manufacturing industry. The R^2 value, which shows the explanatory power of the independent variables on the production, is 90% for the period 2009-2020. The F statistics also expresses the significance of the model and the variables.

In the export model, all variables were found statistically significant. Foreign income (*lnINC*) affects exports positively. The sign of relative prices (*lnPRC*) is

negative, as expected. The results show that the export in the Turkish manufacturing industry increases as relative prices fall and as foreign income rises. The R&D expenditure (*lnRDEX*), which is the control variable of the export demand model, was statistically significant at a 5% significance level. The impact of R&D expenditures is positive on the amount of export in line with the theory. The results show that 1% increase in R&D expenditures increases the export amount in the Turkish manufacturing industry by 0.075%. The R^2 value was found to be 79%, indicating the rate at which our explanatory variables explain the amount of export. The F statistics also expresses the significance of the model and the variables.

Table 3.9. Robust Estimation Results.

Production Model		Export Model	
Variables	Fixed Effect Robust Estimator (Coefficient-Prob.)	Variables	Fixed Effect Robust Estimator (Coefficient-Prob.)
<i>lnCPT</i>	0,057 * (0,058)	<i>lnINC</i>	0,35 *** (0,000)
<i>lnLBR</i>	0,90 *** (0,000)	<i>lnPRC</i>	-0,48 ** (0,021)
<i>lnRDEX</i>	0,038 *** (0,007)	<i>lnRDEX</i>	0,075 ** (0,024)
<i>Constant</i>	0,14 (0,80)	<i>Constant</i>	5,07 *** (0,000)
Observations	264	Observations	264
F statistics	59,08 (0,000)	F statistics	38,99 (0,000)
R-squared	0,90	R-squared	0,79
DW statistics	0,41	DW statistics	0,79
Significance levels: * p<0.10 ** p<0.05 *** p<0.01			

CONCLUSION

Innovation attracts great attention in the field of economics since it provides sustainable growth to economies and brings dynamism to firms and industries. This situation has triggered many theoretical and empirical studies examining the effect of innovation on economic growth. This study addresses the impacts of innovation and technological change on the Turkish manufacturing industry's production and export. Technological change is assumed to develop outside the economic system, apart from the efforts of economic agents in the neoclassical growth model. Afterward, the new growth theories, known as endogenous growth models, rejected this argument. These models acknowledge that technological change emerges as a consequence of the deliberate efforts of firms. In that sense, endogenous technological change has brought a new dimension to growth models.

The endogenous growth approach has gained wide coverage in the literature. Learning by doing, knowledge accumulation, human capital accumulation, externalities and spillovers, R&D activities, product varieties, improving the quality of existing goods, creative destruction based on innovation, foreign trade, openness, imitation, FDI are defined as different components that expected to generate innovation and technological change in an ecosystem. A growing body of empirical work has documented the impact of these factors on the economy through basic innovation indicators such as R&D expenditures, R&D human capital, and the number of patents, etc. Most of the research points to the positive effect of R&D on growth and export.

In the second chapter, the technological structure of the manufacturing industry was presented by various indicators such as the number of enterprises, employment, R&D activities, patent activities, production, and value-added, export and import. The manufacturing industry sub-sectors were grouped as low, medium-low, medium-high, and high technology sectors according to Eurostat's Nace Rev.2 technology intensity classification, and the indicators were conveyed accordingly. In this way, we were able to easily understand which technology-intensive sectors the industry allocates resources to and from which sectors it obtains output. The data

shows that, as of 2020, the majority of the enterprises and the number of employees operate in low-technology sectors. Relatively limited resources have been allocated to high-technology and medium-high-technology sectors, which own 11% of enterprises and 20% of employees. From 2009 to 2020, 72% of the production was obtained from low-technology and medium-low technology sectors. High-technology sectors accomplished only 3% of the remaining production. 3% of the manufactured products were exported by high-technology sectors and 34% by medium high technology sectors. On the import side, the fact that 45% of the import belongs to medium-high-technology sectors indicates a high demand for technology use in the industry. As for our innovation indicators, we notice that 25% of the R&D expenditures belong to high-technology sectors and 58% to medium-high-technology sectors. R&D personnel was predominantly employed by high-technology and medium-high-technology sectors, with 16% and 57% respectively. The statistics show that most of the resources in the manufacturing industry are diverted to low-technology sectors. However, the medium-high technology and high-technology sectors have played a dominant role in allocating resources to innovative activities.

This paper presents empirical evidence on the relationship between sectoral production, export, and R&D expenditures in the Turkish manufacturing industry. The data covering the 2009-2020 period belonging to 22 sub-sectors were collected, and empirical analysis was carried out using panel data analysis methodology. We adopted the R&D expenditure as the innovation indicator of the sub-sectors. We also applied R&D personnel as an alternative proxy for innovation and reported its regression results in the appendix of the thesis. We employed the production function to measure the impact of R&D expenditure on sectoral production. In this equation, capital, labor, and R&D expenditures were used as explanatory variables. The export demand function is another equation we utilized to measure the effect of R&D expenditures on sectoral exports. Foreign income, relative prices, and R&D expenditures are the explanatory variables of this model.

According to the empirical results, capital, labor, and R&D expenditures have a positive impact on the manufacturing industry's production. The labor factor appears to play an important role in explaining the manufacturing industry

production. 1% increase in the labor force leads to 0.90% increase in production. The contribution of the capital, which was proxied with tangible fixed assets value obtained from the sectoral balance sheets, was found to be quite low. 1% increase in the amount of capital increases production by 0.057%. These results suggest that the manufacturing industry has a production structure that exhibits constant returns to scale. Main production factors such as capital and labor contribute to sectoral production in line with the production theory. The high contribution of labor strongly indicates that the Turkish manufacturing industry has a labor-intensive production. As for our innovation indicators, 1% increase in R&D expenditures will prompt an increase of 0.038% in production. Empirical results make clear that the impact of R&D expenditure on production in the manufacturing industry is quite limited. The main reason for this result is the serious sectoral heterogeneity in the industry regarding factor utilization and innovation activities. As we mentioned earlier, low-technology sectors have a significant weight in the industry in terms of factor utilization and output. On the contrary, high-technology and medium-high-technology sectors have a relatively low share in resource allocation and sectoral output despite meeting most of the R&D expenditures.

We also examined the impact of innovative activities on manufacturing industry exports through the export demand function. Competitive advantage in trade can be achieved through either prices or technological knowledge. To this end, foreign income (the income of Turkey's trading partners), relative prices, and R&D expenditure were questioned as to the determinants of export. The results showed that a 1% decrease in relative prices increases the export by 0.48%, and 1% increase in foreign income increases the amount of export by 0.35%. The fact that the exchange rate has a significant effect on the value of foreign income and relative prices can be interpreted as why the coefficients of these variables are close to each other. For innovation indicator, 1% increase in R&D expenditures increases the export by 0.075%. The empirical findings confirmed that the relative prices calculated using REER (Real Effective Exchange Rates) are the most influential explanatory variable and have a greater impact than R&D expenditures on the

amount of export. This indicates that the manufacturing industry has a trading capability based on price competition rather than technological know-how.

Regarding our alternative innovation indicator, the results of which were presented in the appendix, the coefficient of the number of R&D personnel was positive but not statistically significant. A significant contribution of R&D human resources to sectoral production and exports could not be determined. This can be interpreted as implying that steps should be taken to have qualified researchers in the manufacturing industry.

The data and statistics show that the manufacturing industry is far from attaining a high-technology intensive production structure. But, the weight of medium-high-technology sectors in export, R&D activities, and patent applications should not be underestimated. Medium-high-technology sectors could offer promising results for the future in terms of acquiring technological knowledge and innovation.

The empirical findings reported in this thesis confirm the validity of the endogenous growth theory in the Turkish manufacturing industry. However, the contribution of R&D expenditures to sectoral production and export is quite limited. R&D expenditures remain inefficient in scaling up the production and export of the industry. The amount of R&D expenditures is still low despite the significant increases in recent decades. There is also an unequal distribution of R&D expenditures among sub-sectors. Only five sectors held 75% of the R&D spending. This indicates R&D and innovation perspective has not spread to the industry base. For this reason, innovative activities in all sectors should be enhanced in order to make its impact much more evident. Not only the amount but also the productivity of R&D activities poses a problem for the industry.

In addition to the inefficiency and scarcity of innovation activities, we also identified structural problems regarding resource allocation in the Turkish manufacturing industry. The data and statistics show that production resources have been transferred to inefficient sectors where technological knowledge production and value-added potential are relatively low, instead of technology-intensive sectors.

More production factors such as capital, labor, and enterprise should be directed to the high-technology and medium-high-technology sectors to increase high value-added production and exports.

A remarkable finding of the study was that the number of R&D personnel does not have a statistically significant effect on sectoral production and exports. This result implies a question mark regarding the quality of human capital involved in R&D in the industry. To cope with this problem, educational and academic policies should be implemented to get more skilled and productive human capital.

Since technological knowledge is generated in an innovation ecosystem, government, higher education and private sector should work in coordination to improve R&D activities. Non-financial organizations must also take responsibility to overcome the problems revealed by this thesis. A macro-level perspective is needed for a move towards technology-intensive manufacturing activities. In line with sectoral analyses, financial support mechanisms, sectoral incentives, and additional policies to improve the manufacturing industry should be developed to encourage R&D investments. Universities, technology institutions, and other relevant institutions in the innovation ecosystem should be strengthened to produce technological and commercial knowledge that creates economic value.

Future studies can investigate the inefficiency of human capital employed in the R&D in the manufacturing industry by conducting an in-depth analysis. This thesis also recommends a sectoral or firm-based analysis examining the factors affecting total R&D efficiency in the manufacturing industry.

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APPENDIX A

a) Production Model

Pooled Model Estimation

Dependent Variable: LOGPROD
Method: Panel Least Squares
Date: 01/13/22 Time: 09:20
Sample: 2009 2020
Periods included: 12
Cross-sections included: 22
Total panel (balanced) observations: 264

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGCPT	0.124857	0.044154	2.827765	0.0051
LOGLBR	0.889575	0.085335	10.42450	0.0000
LOGRDEX	0.118886	0.026582	4.472348	0.0000
C	-0.531754	0.362658	-1.466269	0.1438
R-squared	0.534862	Mean dependent var	5.046482	
Adjusted R-squared	0.529495	S.D. dependent var	0.311579	
S.E. of regression	0.213722	Akaike info criterion	-0.233243	
Sum squared resid	11.87608	Schwarz criterion	-0.179062	
Log likelihood	34.78803	Hannan-Quinn criter.	-0.211471	
F-statistic	99.65777	Durbin-Watson stat	0.136246	
Prob(F-statistic)	0.000000			

Breusch-Pagan LM Test

Lagrange multiplier (LM) test for panel data
Date: 01/13/22 Time: 09:01
Sample: 2009 2020
Total panel observations: 264
Probability in ()

Null (no rand. effect) Alternative	Cross-section One-sided	Period One-sided	Both
Breusch-Pagan	725.5965 (0.0000)	0.193975 (0.6596)	725.7905 (0.0000)
Honda	26.93690 (0.0000)	-0.440426 (0.6702)	18.73584 (0.0000)
King-Wu	26.93690 (0.0000)	-0.440426 (0.6702)	15.43637 (0.0000)
GHM	-- --	-- --	725.5965 (0.0000)

Fixed Effect Estimation

Dependent Variable: LOGPROD
Method: Panel Least Squares
Date: 01/13/22 Time: 09:23
Sample: 2009 2020
Periods included: 12
Cross-sections included: 22
Total panel (balanced) observations: 264

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGCPT	0.057710	0.039284	1.469052	0.1432
LOGLBR	0.905581	0.098351	9.207609	0.0000
LOGRDEX	0.038498	0.020599	1.868913	0.0629
C	0.142588	0.475229	0.300040	0.7644

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.900689	Mean dependent var	5.046482
Adjusted R-squared	0.885444	S.D. dependent var	0.311579
S.E. of regression	0.105457	Akaike info criterion	-1.534901
Sum squared resid	2.535635	Schwarz criterion	-1.047271
Log likelihood	238.6069	Hannan-Quinn criter.	-1.338957
F-statistic	59.08075	Durbin-Watson stat	0.410093
Prob(F-statistic)	0.000000		

Redundant Fixed Effect Test

Redundant Fixed Effects Tests
Equation: Untitled
Test cross-section and period fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	35.564571	(21,228)	0.0000
Cross-section Chi-square	383.577250	21	0.0000
Period F	3.435673	(11,228)	0.0002
Period Chi-square	40.489662	11	0.0000
Cross-Section/Period F	26.246163	(32,228)	0.0000
Cross-Section/Period Chi-square	407.637759	32	0.0000

Random Effect Estimation

Dependent Variable: LOGPROD
Method: Panel EGLS (Cross-section random effects)
Date: 01/13/22 Time: 09:32
Sample: 2009 2020
Periods included: 12
Cross-sections included: 22
Total panel (balanced) observations: 264
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGCPT	0.115699	0.037386	3.094712	0.0022
LOGLBR	1.158430	0.074061	15.64162	0.0000
LOGRDEX	0.079388	0.019606	4.049131	0.0001
C	-1.590830	0.258294	-6.158989	0.0000
Effects Specification				
			S.D.	Rho
Cross-section random			0.192086	0.7490
Idiosyncratic random			0.111211	0.2510
Weighted Statistics				
R-squared	0.806599	Mean dependent var		0.831896
Adjusted R-squared	0.804367	S.D. dependent var		0.251299
S.E. of regression	0.111150	Sum squared resid		3.212152
F-statistic	361.4514	Durbin-Watson stat		0.445238
Prob(F-statistic)	0.000000			
Unweighted Statistics				
R-squared	0.516315	Mean dependent var		5.046482
Sum squared resid	12.34963	Durbin-Watson stat		0.115807

Hausman Test

Correlated Random Effects - Hausman Test
Equation: RNDRDEXPROD
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	2.716501	3	0.4374

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
LOGCPT	0.112338	0.115699	0.000074	0.6954
LOGLBR	1.179467	1.158430	0.000317	0.2377
LOGRDEX	0.075745	0.079388	0.000013	0.3158

Wald Heteroscedasticity Test

quietly xtreg LOGPROD LOGCPT LOGLBR LOGRDEX i.ID i.DATE, fe
xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: $\sigma(i)^2 = \sigma^2$ for all i

chi2 (22) = 4721.50

Prob>chi2 = 0.0000

Bhargava and Baltagi-Wu Autocorrelation Test

. xtregar LOGPROD LOGCPT LOGLBR LOGRDEX , fe lbi
FE (within) regression with AR(1) disturbances Number of obs = 242
Group variable: ID Number of groups = 22

R-sq: Obs per group:

within = 0.3234 min = 11

between = 0.0999 avg = 11.0

overall = 0.3989 max = 11

F(3,217) = 34.57

corr(u_i, Xb) = -0.1859 Prob > F = 0.0000

LOGPROD Coef. Std. Err. t P>t [95% Conf. Interval]

LOGCPT .037095 .0382095 0.97 0.333 -.0382142 .1124041

LOGLBR 1.029308 .10654 9.66 0.000 .8193224 1.239294

LOGRDEX .0118838 .0139745 0.85 0.396 -.0156594 .039427

_cons -.1232035 .1092326 -1.13 0.261 -.3384963 .0920892

rho_ar .7973832

sigma_u .20590651

sigma_e .06013551

rho_fov .92140874 (fraction of variance because of u_i)

F test that all u_i=0: F(21,217) = 11.92 Prob > F = 0.0000

modified Bhargava et al. Durbin-Watson = .44202562

Baltagi-Wu LBI = .82261698

White Cross Section Robust Estimator

Dependent Variable: LOGPROD

Method: Panel Least Squares

Date: 01/13/22 Time: 09:44

Sample: 2009 2020

Periods included: 12

Cross-sections included: 22

Total panel (balanced) observations: 264

White cross-section standard errors & covariance (d.f. corrected)

WARNING: estimated coefficient covariance matrix is of reduced rank

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGCPT	0.057710	0.030389	1.899039	0.0588
LOGLBR	0.905581	0.117684	7.694996	0.0000
LOGRDEX	0.038498	0.014256	2.700548	0.0074
C	0.142588	0.584364	0.244005	0.8074

Effects Specification

Cross-section fixed (dummy variables)

Period fixed (dummy variables)

R-squared	0.900689	Mean dependent var	5.046482
Adjusted R-squared	0.885444	S.D. dependent var	0.311579
S.E. of regression	0.105457	Akaike info criterion	-1.534901
Sum squared resid	2.535635	Schwarz criterion	-1.047271
Log likelihood	238.6069	Hannan-Quinn criter.	-1.338957
F-statistic	59.08075	Durbin-Watson stat	0.410093
Prob(F-statistic)	0.000000		

b) Export Demand Model

Pooled Model Estimation

Dependent Variable: LOGEXPT
Method: Panel Least Squares
Date: 01/13/22 Time: 09:48
Sample: 2009 2020
Periods included: 12
Cross-sections included: 22
Total panel (balanced) observations: 264

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGINC	0.391890	0.040292	9.726231	0.0000
LOGPRC	-0.731437	0.150523	-4.859306	0.0000
LOGRDEX	0.011626	0.036782	0.316086	0.7522
C	6.318488	0.727498	8.685236	0.0000
R-squared	0.426147	Mean dependent var		5.050993
Adjusted R-squared	0.419526	S.D. dependent var		0.354786
S.E. of regression	0.270307	Akaike info criterion		0.236519
Sum squared resid	18.99713	Schwarz criterion		0.290700
Log likelihood	-27.22053	Hannan-Quinn criter.		0.258291
F-statistic	64.35933	Durbin-Watson stat		0.285539
Prob(F-statistic)	0.000000			

Breusch-Pagan LM Test

Lagrange multiplier (LM) test for panel data
Date: 01/13/22 Time: 09:01
Sample: 2009 2020
Total panel observations: 264
Probability in ()

Null (no rand. effect) Alternative	Cross-section One-sided	Period One-sided	Both
Breusch-Pagan	530.0568 (0.0000)	17.10292 (0.0000)	547.1597 (0.0000)
Honda	23.02296 (0.0000)	4.135568 (0.0000)	19.20398 (0.0000)
King-Wu	23.02296 (0.0000)	4.135568 (0.0000)	16.84860 (0.0000)
GHM	-- --	-- --	547.1597 (0.0000)

Fixed Effect Estimation

Dependent Variable: LOGEXPT
Method: Panel Least Squares
Date: 01/13/22 Time: 09:26
Sample: 2009 2020
Periods included: 12
Cross-sections included: 22
Total panel (balanced) observations: 264

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGINC	0.351220	0.028301	12.41028	0.0000
LOGPRC	-0.489689	0.153876	-3.182355	0.0017
LOGRDEX	0.075373	0.030474	2.473337	0.0141
C	5.079547	0.741536	6.850035	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.796566	Mean dependent var	5.050993
Adjusted R-squared	0.776137	S.D. dependent var	0.354786
S.E. of regression	0.167864	Akaike info criterion	-0.641421
Sum squared resid	6.734594	Schwarz criterion	-0.302789
Log likelihood	109.6675	Hannan-Quinn criter.	-0.505348
F-statistic	38.99282	Durbin-Watson stat	0.790483
Prob(F-statistic)	0.000000		

Redundant Fixed Effect Test

Redundant Fixed Effects Tests
Equation: FIXRDEXEXPT
Test cross-section fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	20.722762	(21,239)	0.0000
Cross-section Chi-square	273.776088	21	0.0000

Random Effect Estimation

Dependent Variable: LOGEXPT
Method: Panel EGLS (Cross-section random effects)
Date: 01/13/22 Time: 09:40
Sample: 2009 2020
Periods included: 12
Cross-sections included: 22
Total panel (balanced) observations: 264
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGINC	0.354925	0.028042	12.65712	0.0000
LOGPRC	-0.521591	0.148065	-3.522715	0.0005
LOGRDEX	0.069389	0.029877	2.322487	0.0210
C	5.238975	0.714973	7.327514	0.0000
Effects Specification				
			S.D.	Rho
Cross-section random			0.223934	0.6402
Idiosyncratic random			0.167864	0.3598
Weighted Statistics				
R-squared	0.640458	Mean dependent var		1.068282
Adjusted R-squared	0.636310	S.D. dependent var		0.277832
S.E. of regression	0.167552	Sum squared resid		7.299124
F-statistic	154.3808	Durbin-Watson stat		0.729565
Prob(F-statistic)	0.000000			
Unweighted Statistics				
R-squared	0.416541	Mean dependent var		5.050993
Sum squared resid	19.31514	Durbin-Watson stat		0.275700

Hausman Test

Correlated Random Effects - Hausman Test
Equation: RNRDREXPT
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	1.034268	3	0.7930

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
LOGINC	0.351220	0.354925	0.000015	0.3324
LOGPRC	-0.489689	-0.521591	0.001755	0.4463
LOGRDEX	0.075373	0.069389	0.000036	0.3189

Wald Heteroscedasticity Test

quietly xtreg LOGEXPT LOGINC LOGPRC LOGRDEX i.ID, fe
xttest3
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model
H0: $\sigma(i)^2 = \sigma^2$ for all i
chi2 (22) = 303.02
Prob>chi2 = 0.0000

Bhargava and Baltagi-Wu Autocorrelation Test

xtregar LOGEXPT LOGINC LOGPRC LOGRDEX , fe lbi
FE (within) regression with AR(1) disturbances Number of obs = 242
Group variable: ID Number of groups = 22
R-sq: Obs per group:
within = 0.2201 min = 11
between = 0.1013 avg = 11.0
overall = 0.3693 max = 11
F(3,217) = 20.41
corr(u_i, Xb) = 0.0498 Prob > F = 0.0000
LOGEXPT Coef. Std. Err. t P>t [95% Conf. Interval]
LOGINC .2013837 .0359512 5.60 0.000 .1305255 .272242
LOGPRC -.5137607 .1368105 -3.76 0.000 -.7834083 -.2441132
LOGRDEX -.0009862 .0283796 -0.03 0.972 -.0569212 .0549488
_cons 6.470523 .2538125 25.49 0.000 5.97027 6.970777
rho_ar .64741713
sigma_u .24044796
sigma_e .11539381
rho_fov .81279976 (fraction of variance because of u_i)
F test that all u_i=0: F(21,217) = 8.64 Prob > F = 0.0000
modified Bhargava et al. Durbin-Watson = .7276042
Baltagi-Wu LBI = 1.1249943

White Cross Section Robust Estimator

Dependent Variable: LOGEXPT

Method: Panel Least Squares

Date: 01/13/22 Time: 09:53

Sample: 2009 2020

Periods included: 12

Cross-sections included: 22

Total panel (balanced) observations: 264

White cross-section standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGINC	0.351220	0.052261	6.720489	0.0000
LOGPRC	-0.489689	0.211955	-2.310341	0.0217
LOGRDEX	0.075373	0.033200	2.270267	0.0241
C	5.079547	0.991953	5.120756	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.796566	Mean dependent var	5.050993
Adjusted R-squared	0.776137	S.D. dependent var	0.354786
S.E. of regression	0.167864	Akaike info criterion	-0.641421
Sum squared resid	6.734594	Schwarz criterion	-0.302789
Log likelihood	109.6675	Hannan-Quinn criter.	-0.505348
F-statistic	38.99282	Durbin-Watson stat	0.790483
Prob(F-statistic)	0.000000		

APPENDIX B

Regression results of the number of R&D personnel as an alternative proxy for innovation:

a) Production Model

Dependent Variable: LOGPROD

Method: Panel Least Squares

Date: 01/13/22 Time: 09:58

Sample: 2009 2020

Periods included: 12

Cross-sections included: 22

Total panel (balanced) observations: 264

White cross-section standard errors & covariance (d.f. corrected)

WARNING: estimated coefficient covariance matrix is of reduced rank

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGCPT	0.055283	0.030902	1.788960	0.0749
LOGLBR	0.947717	0.120495	7.865187	0.0000
LOGRDLB	0.008447	0.015828	0.533670	0.5941
C	0.107912	0.665692	0.162105	0.8714

Effects Specification

Cross-section fixed (dummy variables)

Period fixed (dummy variables)

R-squared	0.899217	Mean dependent var	5.046482
Adjusted R-squared	0.883746	S.D. dependent var	0.311579
S.E. of regression	0.106236	Akaike info criterion	-1.520181
Sum squared resid	2.573235	Schwarz criterion	-1.032551
Log likelihood	236.6639	Hannan-Quinn criter.	-1.324237
F-statistic	58.12227	Durbin-Watson stat	0.401029
Prob(F-statistic)	0.000000		

b) Export Demand Model

Dependent Variable: LOGEXPT

Method: Panel Least Squares

Date: 01/13/22 Time: 10:00

Sample: 2009 2020

Periods included: 12

Cross-sections included: 22

Total panel (balanced) observations: 264

White cross-section standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGINC	0.388435	0.064119	6.057997	0.0000
LOGPRC	-0.569895	0.211185	-2.698559	0.0075
LOGRDLB	0.020341	0.038179	0.532779	0.5947
C	5.547071	0.997055	5.563457	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.791588	Mean dependent var	5.050993
Adjusted R-squared	0.770660	S.D. dependent var	0.354786
S.E. of regression	0.169905	Akaike info criterion	-0.617247
Sum squared resid	6.899379	Schwarz criterion	-0.278615
Log likelihood	106.4766	Hannan-Quinn criter.	-0.481174
F-statistic	37.82367	Durbin-Watson stat	0.775850
Prob(F-statistic)	0.000000		