INTERNATIONAL TECHNOLOGY DIFFUSION AND PRODUCTIVITY CHANGE IN THE TURKISH MANUFACTURING SECTOR*

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Abstract

Most new technologies are created in developed countries. In developing countries, contacts with the outside world, research and development (R&D), human capital, and technology diffusion play important roles in increasing innovation and productivity. Using panel data from manufacturing sectors from 2009 to 2014, this study examines the impact of various channels of technology diffusion, R&D, and human capital on labour productivity change in Turkey. According to the estimation results, the technology gap has had a positive effect on productivity change. This suggests a rapid adaptation to technology, and it may be a sign of future convergence with the technological frontier. Export intensity, improves technology transfer rate. Increase in export intensity is found to increase productivity change for the following year; and, increase in import penetration on productivity change is found to be positive in the current year and in the subsequent years. The impacts of foreign direct investments (FDI), tangible investments, R&D intensity, and human capital are found to be insignificant, while the impact of interaction of human capital with the technology gap is negative and significant. It is also found that increases in the market concentration rate, the Herfindahl-Hirschman Index (HHI), results in more rapid increases in productivity.

Keywords: Productivity, technology diffusion, R&D, human capital, developing countries.

JEL Classification: O30, O31, O33, O14, O41.

TÜRKİYE İMALAT SEKTÖRÜNDE ULUSLARARASI TEKNOLOJİ DİFÜZYONU VE VERİMLİLİK DEĞİŞİMİ

Öz

Çoğu yeni teknoloji gelişmiş ülkelerde yaratılmaktadır. Gelişmekte olan ülkelerde, dış dünya ile temaslar, araştırma ve geliştirme (Ar-Ge), beşeri sermaye ve teknoloji difüzyonu, inovasyon ve verimliliğin artmasında önemli rol oynamaktadır. Bu çalışma, 2009-2014 yılları arasında Türkiye imalat sektörü panel verilerini kullanarak çeşitli teknoloji difüzyonu kanalları, Ar-Ge ve beşeri sermayenin işgücü verimliliğindeki değişmeye etkilerini incelemektedir. Tahmin sonuçlarına göre, teknolojik açığın verimlilik değişimine etkisi pozitiftir. Bu, teknolojiye hızlı bir şekilde uyum sağlandığını ve gelecekte teknoloji sınırına yakınlaşmanın gerçekleşebileceğini göstermektedir. İhracat yoğunluğu, teknoloji transfer hızını artırmaktadır. İhracat yoğunluğundaki artışın, bir sonraki yılda verimliliği arttırdığı; ithalat yoğunluğundaki artışın verimlilik değişimine etkisinin de cari yılda ve sonraki yıllarda pozitif olduğu görülmüştür. Doğrudan yabancı yatırımların, maddi yatırımların, Ar-Ge yoğunluğunun ve beşeri sermayenin etkileri anlamsızken; beşeri sermaye ile teknoloji açığı etkileşiminin verimliliğe etkisi, negatif ve anlamlıdır. Ayrıca, piyasa yoğunluğundaki, Herfindahl-Hirschman Endeksi (HHI) artışlarının verimlilikte daha hızlı artışlara neden olduğu bulunmuştur.

Anahtar Kelimeler: Verimlilik, teknoloji difüzyonu, Ar-Ge, beşeri sermaye, gelişmekte olan ülkeler.

JEL Sınıflaması: O30, O31, O33, O14, O41.

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1. Introduction

Due to the acceleration of the globalisation process in the 1990s, more developing countries experienced rapid economic growth and a narrowing income gap in comparison to developed countries. Today, trade and foreign direct investments have seen a large increase, which has created mutual benefits for developed and developing countries and has led to the diffusion of knowledge between these countries. However, most new technology is still created in developed countries due to high human capital levels. Since developed countries can afford innovation, they often attempt to apply effective patent protections for these innovations. But knowledge is partially excludable, and it can diffuse from frontier to follower countries. Since labour costs are low in developing countries, they often try to imitate or copy to save on costs. Despite the fact that the productivity of research depends on the individual scientific, engineering, and industrial experiences of the country, as the number of contacts with the outside world increases, domestic knowledge capital stock increases. The international spread of knowledge occurs via international trade and foreign investments.

However, productivity differences between developed and developing countries remain steady. The factors behind these large productivity differences can include differences in institutional infrastructure, geography, natural resources, and financial development. According to researchers, developing countries can only use new technology as effectively as they can assimilate. The ability to use knowledge and increase the speed of the catch-up depends on the level of human capital. Moreover, human capital and research and development (R&D) investments are needed in order for new technology to be adapted for domestic production. As countries increase their adoptive capacity and technology diffusion, their productivity increases more rapidly and their productivity level is able to converge with the frontier country's productivity level.

The aim of this study is to determine the impacts of exports, imports, foreign direct investments (FDI), R&D and human capital on labour productivity change in 22 manufacturing sub-sectors in Turkey between 2009 and 2014. The two primary sources of productivity growth in the technology frontier are innovation and technology transfer. Differences in the levels of labour productivity between Turkey and the frontier country (Germany) is a measure of potential technology transfer. Technology transfer is used to detect convergence in industries over time, and R&D, human capital and interaction terms with the technology gap, will show each variable's direct effect on productivity growth (innovation) and indirect effect on speed of technology diffusion. This study uses fixed effects panel data analysis to correct for potential heteroscedasticity in the cross-sectional dimension (Kutan and Yigit, 2009, p. 133) after the Hausman test for random or fixed effects.

The remainder of this paper is organised as follows: in the next section, theoretical and empirical work on technology diffusion is discussed in detail, while the third section introduces the theoretical model the study is based on. The fourth section provides information about the data, methodology, descriptive statistics, and stylised facts about the Turkish manufacturing industry. The empirical model and results of the analysis will be presented in the fifth section. The last section includes a brief conclusion and policy recommendations.

2. Literature Review

Technology transfer from leader to follower countries is an important source of economic growth. Nelson and Phelps (1966) emphasised the importance of human capital for the process of technology diffusion. Benhabib and Spiegel (2005, p. 937) cited Nelson and Phelps's model for economic growth, based on two hypotheses. The first hypothesis is that the speed of international technological development depends on how rapidly new discoveries are made, and growth in the technological frontier is always affected by these innovations. In follower countries, the greater the technological distance between the technology frontier and the level of productivity, the higher the rate of productivity growth will be. The second hypothesis states that the rate at which the technology gap is closed depends on the country's adoptive capacity, which is determined by the level of human capital. As human capital increases, the speed of technology diffusion increases and productivity growth increases, and thus, the productivity of the follower country can converge with that of the leader. Benhabib and Spiegel (2005, p. 936) discussed a critical level of human capital required by a follower country in order to achieve a faster productivity growth than the leading country. They could explain the divergence of 22 of 27 less developed countries between 1960 and 1995, but they could not explain the convergence of Asian tigers.

According to Grossman and Helpman (1991, p. 518), the productivity of research studies depends on the scientific, engineering, and industrial knowledge of the country, i.e., the knowledge capital stock. As the country's number of contacts with the outside world increases, local knowledge capital accumulates. These contacts come in the forms of contact between personnel from different firms, seminars abroad, fairs, and the volume of international trade. Whichever kinds of contact occur, they bring with them the spread of information and the accumulation of knowledge.

Trade openness may lead to increased productivity due to: 1) the introduction of foreign goods, competition, and quality improvement in domestic production; 2) variety in inputs; and 3) the diffusion of technology. Rodrik (as cited in Taymaz and Yılmaz, 2007, p.127), however, raised the opposite perspective. If the market shares of local producers are reduced and the competitiveness of producers decreases due to the liberalisation of trade, the increase in the cost of new technology may actually reduce productivity and lead to a backward slide.

Technology transfer and innovation are two sources of productivity growth for a country that is behind the technology frontier. Human capital and R&D are important in both technological catch-up and innovation. Redding et al. (2004, p. 893), using a panel of industries across 12 OECD countries between 1974 and 1990, showed that R&D can increase growth directly, through innovation, and indirectly, through technology transfer. Thus, R&D plays a significant role in the convergence of total factor productivities between OECD countries. Cameron et al. (2005, p. 775), in a study of the productivity growth in 14 UK manufacturing industries between 1972 and 1992, indicated that technology transfer is statistically significant, R&D increases rates of innovation, and international trade increases the speed of technology transfer. Kutan and Yigit (2009, p. 127) analysed productivity growth in eight new European Union countries. They found that these countries showed significant growth toward catching up with EU15 countries, and that while FDI, exports, and human capital enhance productivity, imports hurt it.

International technology diffuses through imports, exports, and FDI (see related literature in Keller, 2004). Coe and Helpman (1995) stated that foreign and domestic R&D provide potential for technology transfer that can lead to technology diffusion and innovation, and that technology diffusion is related to imports of capital goods from developed countries. Sjöholm (1996) claimed that an increase in imports led to an increase in patent applications in Swedish firms. According to Eaton and Kortum (2001), countries that have an intensive focus on R&D specialise in intermediate production, while developing countries import most of their intermediate goods. According to Taymaz and Yılmaz (2007), trade openness causes an increase in productivity due to the introduction of foreign goods, competition, quality improvement in domestic production, introduction of various inputs, and diffusion of technology. Imports provide access to foreign commodities and the technology they contain.

The relationship between exports and productivity growth is a much-debated topic in the literature. Exports have a positive effect on learning and on the demand of foreign markets for higher product quality standards. Export firms are more efficient than non-exporters as they have invested more in increasing productivity and the quality of goods. More productive firms are closer to the frontier, so they tend to invest more in R&D and grow faster. Clerides et al. (1998), in their study of manufacturing plants in Columbia, Morocco, and Mexico in the 1980s, found that when firms exit the export market, their costs and productivities decrease. Bernard and Jensen (1999) claimed that labour productivity growth in US export firms is 0.8% higher than non-exporters, and that the survival of export firms is 10% higher. There are two things to consider when investigating this issue. First, it is necessary to examine the effect of learning by exporting in high technology industries, and second, it is important to consider the properties of exporters and destination countries. Taymaz and Yılmaz (2007) analysed productivity changes in Turkish manufacturing firms before and after the customs union, between 1984 and 2000. They found that productivity gains were higher in import-competing sectors than in export-oriented and non-traded sectors.

FDI as a channel of technology diffusion is also a much-debated topic in the literature, and recent studies show that FDI spillovers are important to consider. Multinational companies share their technologies with international partners and subsidiaries, by labour training and labour turnover or by providing technologically advanced intermediate inputs to domestic firms (Rodriguez-Clare, 1996, and Fosfuri et al., 2001). According to the UNCTAD Report (2011), the importance of inward FDI is increasing in developing countries. Export-oriented production is developed using imported technologies; foreign subsidiaries establish backward relationships with domestic firms, which is important for technology externalities, and foreign subsidiaries report specifications to local suppliers in order to maintain technological standards that will help improve their technological capabilities.

Turkish studies have analysed innovation and technology transfer through R&D and various channels of knowledge diffusion. But the effect of potential technology transfer (the technological distance from the technology frontier) has not yet been studied. Lenger and Taymaz (2006) have shown that R&D intensity increases innovation and productivity in foreign firms in the manufacturing sector of Turkey, but they have also shown that it cannot be transferred through passive spillovers or without in-house technological activities. The work of Meschi et al. (2011) indicated a positive effect of R&D expenditures, technological transfers from abroad, foreign ownership, and exporting on skill upgrading. In terms of international technology diffusion and productivity in Turkey, Taymaz and Saatci (1997) examined the technical efficiency of the textile, cement and motor vehicle industries in a very detailed study, and they found a positive impact of foreign ownership in the motor vehicle industry. Pamukcu (2003) indicated that trade liberalisation had a positive impact on firms' innovation decisions through technology embodied in imported machinery, however, technology licences, exports, and foreign shares had no significant impact. Yasar and Morrison Paul (2007) showed that FDI, exports, imports, and licensing have a positive impact on productivity in Turkish manufacturing plants in the apparel, textiles, and motor vehicle industries. Ulku and Pamukcu (2015) concluded that foreign ownership and technology licensing increase firms' productivity in the manufacturing sector, but that R&D intensity and industry R&D spillovers increase productivity only in those firms with technological capability that falls above a critical level.

3. Data and Variables

In this study, an Annual Industry and Service Statistics (AISS) micro dataset provided by TurkStat was used. The period of study was between 2009 and 2014. The AISS dataset is an enterprise-level dataset that includes detailed information about turnover, production, value added, number of employees, and capital investments. This study used enterprises with more than 20 employees, the data for which was collected by full enumeration method by TurkStat. Furthermore, an R&D statistics micro dataset was merged with the AISS dataset, using enterprise identification numbers. Foreign trade statistics were provided by the TurkStat website. Firm-level data was then aggregated to manufacturing sub-sector levels, according to the NACE Rev. 2 classification system. Value added at factor costs were deflated based on yearly sub-sector producer price indexes for 2010.

Table 1: Variables and definitions

Variables	Definitions
$\Delta ln(LP)_{jt}$	Labour productivity change: $ln(LP)_{jt} - ln(LP)_{jt-1}$, where t is time, j is sector.
$EXINT_{jt}$	Export Intensity: $\frac{Exports_{jt}}{Turnover_{jt}}$
$IMPEN_{jt}$	Import Penetration: $\frac{Imports_{jt}}{Market\ Size_{jt}} = \frac{Imports_{jt}}{Turnover_{jt} - Exports_{jt} + Imports_{jt}}$
TG_{jt-1}	Technology Gap: $\ln\left(\frac{A_{Fjt-1}}{A_{jt-1}}\right)$, where A_{Fjt-1} is labour productivity of the technology frontier, Germany. A_{jt-1} is labour productivity of Turkey.
$FORSH_{jt}$	Share of foreign firms' turnover in sector. Foreign firms are the firms with 10% or more foreign capital shares.
$RDINT_{jt}$	R&D expenditures/sector turnover: Ratio of R&D expenditures to total sector turnover
$TANGINV_{jt}$	Tangible investment intensity: The ratio of tangible investments to total turnover
HHI_{jt}	HHI: $S_{jk} = \frac{turnover_{jk}}{turnover_j}$, $HHI_j = \sum_{k=1}^{n}(S_{jk})^2$ is cumulative share of turnover of the all enterprises in the industry, where j is sector and k is enterprise.
HC_{jt}	Human capital as returns to tertiary education: $\frac{hrealwage\_university_{jt} - hrealwage\_vochighschool_{jt}}{15 - 11}$

4. Some Facts about the Manufacturing Industry in Turkey

In Turkey's manufacturing sector and its sub-sectors, productivities fluctuate yearly.[2] Turkey mainly exports to and imports from European Union countries, especially Germany.[3] Therefore, when taking the distance from the technology frontier into consideration and bearing in mind that Germany's data is available in the Eurostat, Germany can be considered a frontier country for Turkey. The technology gap is $\ln\left(\frac{A_{Fjt}}{A_{jt}}\right)$, where A_{Fjt} is the labour productivity of the technology frontier and A_{jt} is the labour productivity of Turkey. Monetary values gathered from Eurostat were expressed in millions of euros. Germany's

2 In the Appendix B, Figure B1 and B2 shows labour productivities and average annual changes in labour productivity in manufacturing sub-sectors between 2008 and 2014.

3 In the Appendix C, Table C1 shows export and import shares by countries in 2014.

value added at factor costs are converted to Turkish lira values by using Turkish Foreign Trade Statistics, with the total exports expressed in euros and Turkish liras. With the help of exports in euros and Turkish lira values, the exchange rates for each sector were obtained. Value added at factor costs were not deflated, and nominal value added at factor costs were divided by the number of persons employed. It can be seen in Table 2 that the technology gap between Turkey and the technology frontier fluctuates yearly, which is the case for labour productivity in all sectors.

Table 2: Technology gap between Turkey and Germany by sectors, between 2008 and 2014

Sector	**Productivity Gap**						
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
High Technology							
21	2.94	3.15	2.80	3.71	3.39	3.40	3.77
26	2.60	1.66	2.49	2.43	2.55	2.08	2.66
Medium-High Technology							
20	2.23	2.15	2.54	2.28	2.28	2.11	2.29
27	2.17	2.09	2.62	2.84	2.85	2.37	2.86
28	3.58	3.13	3.24	3.38	3.35	3.08	3.43
29	2.43	2.13	2.73	2.92	3.19	3.02	4.04
30	2.78	2.86	2.46	2.36	2.61	2.84	2.35
Medium-Low Technology							
19	1.14	1.03	2.05	1.10	1.50	1.67	1.36
22	2.34	2.09	2.39	2.47	2.50	2.34	2.57
23	2.42	2.48	2.45	2.58	2.71	2.45	2.63
24	1.49	2.42	1.68	1.50	2.07	1.64	1.76
25	3.00	2.72	2.99	3.11	3.02	2.96	3.06
Low Technology							
10	1.69	1.90	1.77	1.93	1.79	1.81	1.95
11	1.07	1.08	1.09	1.42	1.35	1.64	1.77
12	3.19	3.76	1.38	2.04	1.21	1.31	1.11
13	3.22	2.89	3.11	2.97	3.15	2.79	3.09
14	5.40	5.34	5.17	5.30	5.35	5.09	5.72
15	3.92	4.11	3.91	4.25	4.02	3.74	4.26
16	1.57	1.65	1.73	1.92	1.53	1.89	1.86
17	2.92	2.73	2.59	2.48	2.39	2.47	2.56
18	2.79	2.68	2.57	2.84	2.78	2.55	2.94
31	4.19	3.71	3.81	4.28	4.25	3.79	4.20
32	3.46	3.17	3.19	3.45	3.47	3.39	3.46
33	3.12	2.64	3.16	3.34	3.39	4.35	3.89

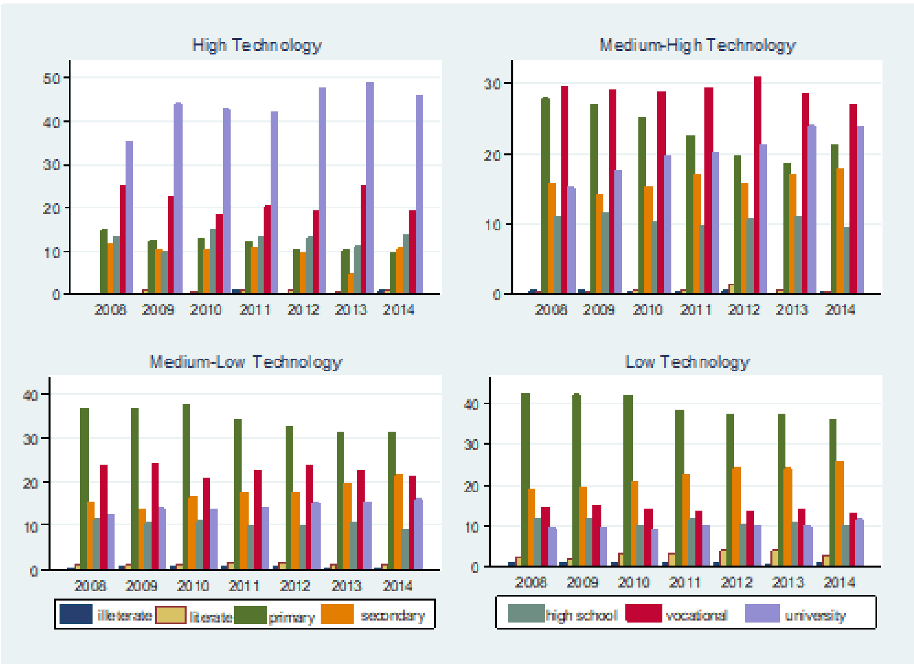
Source: Author's own calculation from AISS data from TurkStat and Structural Business Statistics from Eurostat

In general, net exporter sectors (with export-import ratios of greater than 1) are low technology and medium-low technology sectors. However, the high technology and medium-high technology sectors are net importer sectors (with export-import ratios of less than 1).

Some of the medium-low technology sectors, such as coke and petroleum products (19) and basic metals (24), and some of the low technology sectors such as tobacco (12), leather products (15), wood and products of wood (16), paper products (17), and recorded media (18) are net importers. Medium-high technology sectors such as the electrical equipment (27) and motor vehicles (29) sectors are both exporters and importers. Export intensity, import penetration, and export-import ratios for each sector can be seen in Appendix D, Table D.1. Productivity levels and changes in productivity are higher in import-competing sectors than in net exporter sectors.

As shown in Figure 1, the group with the highest share in manufacturing employment was those who graduated from primary school between 2008 and 2014. However, the share of primary school graduates showed a gradual decrease, while the share of secondary school graduates and university graduates increased gradually. As shown in Figure 1, high technology sectors employed more university graduates than other sectors. In the medium-high technology sectors, vocational school graduates were relatively important, and the share of university graduates increased gradually. In the medium-low and low technology sectors the share of primary graduates was relatively higher.

Figure 1: Employment by education by groups of sectors, between 2008 and 2014



Source: Author's own calculation from Household Labour Force Survey data from TurkStat

5. Model and Estimation Results

Theoretical framework is based on Bernard and Jones (1996a, b) and Cameron et al. (2005) and Kutan and Yigit (2009). Total productivity growth for a country behind the technology frontier is result of innovation and technology transfers from other countries:

(1) $$\Delta \ln A_{jt} = \gamma_j + \lambda_j ln(\frac{A_{Fjt-1}}{A_{jt-1}}), \quad \gamma_j, \lambda_j \geq 0$$

where t=1, ..., T corresponds to time, j=1, ..., J corresponds to sector, for less advanced country behind technology frontier and F is technology frontier (Germany) with higher level of productivity than the other country. γ_j corresponds to rate of innovation in the sector and λ_j corresponds to rate of technological transfer. The further the country behind the technology frontier the larger the λ_j and the greater the potential for productivity growth by technology transfer.

According to Cameron et al. (2005) both γ_j and λ_j are time varying. Both of innovation (γ_j) and rate of technology transfer (λ_j) are determined by various channels of technology diffusion, and levels of R&D and human capital.

(2) $$\gamma_{jt} = \eta_j + \delta Z_{jt-1}, \quad \lambda_{jt} = \theta + \mu Z_{jt-1}$$

The earlier equation (1) for productivity growth in sector j of country (Turkey) becomes:

(3) $$\Delta \ln A_{jt} = \eta_j + \delta Z_{jt-1} + \theta ln\left(\frac{A_{Fjt-1}}{A_{jt-1}}\right) + \mu Z_{jt-1}\left(\frac{A_{Fjt-1}}{A_{jt-1}}\right) + \varepsilon_{jt}$$

where δZ_{jt-1} denotes direct effect on innovation rate and interaction term $\mu Z_{jt-1}(A_{Fjt-1}/A_{jt-1})$ denotes effect on the speed of technology transfer.

In the model I estimate, innovation (γ_j) is determined by channels of technology diffusion (exports, imports and FDI), R&D and human capital. λ_{jt} is a function of R&D and human capital in order to detect the effect of absorptive capacity on the speed of technology transfer. In conclusion the model I estimate is as follows:

(4) $$\Delta \ln A_{jt} = \eta_j + \alpha X_{jt} + \delta W_{jt-1} + \theta ln\left(\frac{A_{Fjt-1}}{A_{jt-1}}\right) + \mu Z_{jt-1}\left(\frac{A_{Fjt-1}}{A_{jt-1}}\right) + \varepsilon_{jt}$$

where A_{jt} is the labour productivity, for Turkey, j denotes sectors and t denotes time and F denotes technology frontier (Germany). Here, X_{jt} is the vector of variables with synchronous effects and W_{jt-1} is the vector of variables with lagged effects. Export intensity, import penetration, R&D and human capital may have lagged effects. FDI, tangible investment and market concentration have contemporaneous effects on labour productivity (Kutan and Yigit, 2009, p. 134). $\mu Z_{jt-1}(A_{Fjt-1}/A_{jt-1})$ denotes effect on the speed of technology transfer, where $Z_{jt-1}$is the vector of variables of absorptive capacity, R&D intensity and human capital.

For this estimation, the tobacco (12) and repair and installation of machinery (33) sectors were ignored due to data unavailability. Information on Germany's productivity before 2005 was not available, and it was missing for some sectors in some years until 2008. Therefore, the time dimension for this study falls between 2009 and 2014. A fixed effects panel data analysis was used to correct for potential heteroscedasticity in the cross-sectional dimension (Kutan and Yigit, 2009, p. 133) after running the Hausman test for random or fixed effects. Furthermore, autocorrelation, cross-sectional dependency, and heteroscedasticity problems in the data were tested for; therefore, Driscoll-Kraay estimators were found to be suitable for the model.

Table 3: Productivity change, fixed-effects estimations with Driscoll-Kraay standard errors

	(1)	(2)
TG(-1)		0.53*** (0.11)
RDINT	0.21 (4.66)	0.31 (5.09)
HC	-0.02 (0.01)	-0.01 (0.01)
IMPEN	1.54** (0.47)	1.34** (0.47)
EXINT	-1.17* (0.57)	-0.88** (0.53)
FORSH	0.24 (0.23)	0.15 (0.23)
TANGINV	-0.15 (1.39)	-0.32 (1.10)
HHI	5.57*** (0.95)	7.14*** (0.56)
Constant	- 0.64*** (0.10)	-1.24*** (0.06)
R-squared	0.2036	0.3578
F Stat	512.88	255.06
Prob>F	0.0000	0.0000
Observations	132	132
Sectors	22	22

Note: Random effects are rejected and fixed effects results are presented above. Autocorrelation, cross-sectional dependency, and heteroscedasticity problems in the data were tested for; therefore, Driscoll-Kraay estimators were found to be suitable for the model. Driscoll-Kraay standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

According to estimation results in Table 3, the effects of import penetration and market concentration on changes in labour productivity are positive and significant. However, the effects of foreign presence, tangible investment intensity, R&D intensity, and human capital are insignificant. If one lagged effect of the technology gap is included in the model, the coefficient is positive and significant. Theoretically, we can expect the technology gap to have a lagging effect on technology. Moreover, the positive effect of distance to the technology frontier suggests a rapid adaptation to the technology, and it may be an indication of a convergence with the technology frontier in the future. According to these results, the relationship between import penetration and changes in labour productivity is positive and significant. And, the relationship between export intensity and changes in labour productivity is negative and significant. Here, there is a moderate positive correlation between export intensity and import penetration (~0.68), as can be seen in the table of correlations.[4] In addition, there is a positive weak correlation between export intensity and R&D intensity (~0.42), and a positive moderate correlation between import penetration and R&D intensity (~0.62). These results can be interpreted to show that Turkey can increase its product variety by imports, which facilitates access to a variety of products at all quality levels, which can, in turn, improve productivity. Moreover, products are exported mainly to European Union and high technology countries, which shows that Turkey is able to compete in these high technology markets. Exporting to these markets adversely affects the change in productivity in Turkey, but Turkey is still able to compete in the international market. The relationship between the Herfindahl-Hirschman Index (HHI) and the change in productivity is also positive and significant. Therefore, as the market concentration, the HHI, increases, productivity increases more rapidly.

[4] In the Appendix E, Table E1 shows correlations between variables.

Table 4: Productivity change, interaction effects, fixed-effects estimations with Driscoll-Kraay standard errors

Dependent Variable: $\Delta ln\,(LP)$								
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
TG(-1)	0.52***	0.43***	0.59***	0.39**	0.20	0.24	-0.08	0.33
	(0.10)	(0.08)	(0.09)	(0.15)	(0.16)	(0.18)	(0.11)	(0.31)
RDINT(-1)	2.57	-4.13	2.46	2.75	3.32	3.32	3.67	-4.97
	(3.35)	(6.39)	(3.36)	(3.27)	(3.06)	(3.14)	(2.76)	(10.13)
HC(-1)	-0.020	-0.020	0.001	-0.004	-0.008	-0.011	-0.030	-0.023
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
IMPEN (-1)	0.90*	0.94*	0.91*	0.49	1.42**	1.36**	0.72**	1.79*
	(0.44)	(0.46)	(0.39)	(0.50)	(0.40)	(0.42)	(0.22)	(0.89)
EXINT	-0.11	-0.16	-0.16	-0.21	-2.46***	-2.51***	-2.10***	-2.53***
	(0.26)	(0.25)	(0.25)	(0.26)	(0.33)	(0.34)	(0.45)	(0.36)
FORSH	0.22	0.20	0.28	0.32	0.35	0.66	0.35	0.82*
	(0.28)	(0.26)	(0.31)	(0.30)	(0.26)	(0.36)	(0.20)	(0.35)
TANGINV	-0.26	-0.40	-0.23	-0.23	0.10	0.18	0.03	0.05
	(1.10)	(1.08)	(1.08)	(1.07)	(0.66)	(0.66)	(0.73)	(0.58)
HHI	7.70***	7.22***	7.73***	7.47***	8.56***	8.51***	8.01***	8.15***
	(1.01)	(1.19)	(0.93)	(1.07)	(1.03)	(0.90)	(1.20)	(0.97)
TG*RDINT		7.81						9.40
		(4.96)						(8.58)
TG*HC			-0.07**	-0.06**	-0.05*	-0.05		
			(0.02)	(0.02)	(0.02)	(0.03)		
TG*IMPEN				0.43	-0.74*	-0.73*		-1.18
				(0.22)	(0.34)	(0.36)		(0.74)
TG*EXINT					2.19***	2.25***	1.82***	2.29***
					(0.31)	(0.32)	(0.34)	(0.32)
TG*FORSH						-0.37		-0.69
						(0.32)		(0.36)
Constant	-1.37***	-1.24**	-1.40***	-1.19**	-1.04***	-1.07***	-0.76**	-1.14**
	(0.30)	(0.33)	(0.28)	(0.34)	(0.23)	(0.23)	(0.23)	(0.35)
R-squared	0.3373	0.3503	0.3507	0.3560	0.4493	0.4531	0.4302	0.4563
F Stat	1554.26	42.49	2509.99	103.41	121.61	123.22	299.64	61.73
Prob>F	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
Observations	132	132	132	132	132	132	132	132
Sectors	22	22	22	22	22	22	22	22

Note: Random effects are rejected and fixed effects results are presented above. Autocorrelation, cross-sectional dependency, and heteroscedasticity problems in the data were tested for; therefore, Driscoll-Kraay estimators were found to be suitable for the model. Driscoll-Kraay standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

According to estimation results in Table 4, when interaction effects and lagged variables are included in the model, the effect of export intensity is negative and significant. However, as can be seen in the estimation results in Appendix E Table E2 the effect of one lagged export intensity is positive and significant. An increase in exports hurts productivity in the current year, but, improves productivity in the next year. Thus, competing in developed EU countries increases productivity change in the subsequent year. If firms must incur high sunk costs to enter the export market, their early productivity will be adversely affected (Roberts and Tybout, 1997). However, once they recover these initial costs, their productivity will improve in the next years. The positive effect of one lagged import intensity implies that import penetration increases productivity in the next year also. The effects of one lagged R&D and one lagged return to tertiary education are insignificant.

Technology transfer rate is affected by human capital (one lagged return to tertiary education), import penetration and export intensity. Export intensity improves technology transfer, but import penetration and return to tertiary education hurts it. Relative wage of tertiary education, the return to tertiary education, decreases technology transfer rate if the technology gap is high. The mismatch between human capital and technology increases if the technology gap is high, which adversely affects the change in productivity. The interaction effect of R&D is positive but insignificant. Also, technology transfer rate is not affected by the foreign presence in the industry. As Ulku and Pamukcu (2015) also states, R&D intensity and industry R&D spillovers increase productivity only in those firms with technological capability that falls above a critical level; therefore, for technology diffusion and improvement in productivity, R&D investments are needed and especially in-house R&D investments should be encouraged in Turkey.

6. Conclusion

This study examines the impacts of exports, imports, FDI, R&D, and human capital on technology diffusion in Turkey's 22 manufacturing sub-sectors between 2009 and 2014.

Theoretically, we expect the technology gap to have a lagging effect on the increase in productivity, and that as the gap increases, productivity will increase more rapidly. There is a swift adaptation to technology, which may be a sign of a future convergence with the frontier. According to the estimation results, the relationship between import penetration and change in labour productivity is positive and significant, that is, import penetration cause an immediate increase in productivity. The effect of one lagged import intensity is also positive and significant. It is known that imports primarily constitute capital goods or higher quality products in Turkey, therefore, this improves productivity change. Moreover, the exports are mostly to European Union and high technology countries, which shows that Turkey can compete in these high technology markets. The effect of one lagged export intensity is found to be positive and significant, therefore, an increase in exports is found to improve productivity in the next year. Export intensity, also, improves technology transfer. Therefore, Turkey absolutely benefits from exporting to high technology countries. As an economic policy, it may also be recommended to establish trade relationships not only with high technology countries, but also with low technology countries.

The effects of one lagged R&D and one lagged return to tertiary education are insignificant. The effect of the interaction of R&D with the technology gap is positive but insignificant. However, R&D investments in Turkey will still be necessary for technology diffusion. Low technology industries are more competitive, and export to high technology countries. The sectors, with a high technology level that require R&D studies, have higher expenditures on software, patents, and rights and higher human capital utilisation. Thus, as a policy suggestion, Turkey should increase R&D investments, especially in-house R&D, in these sectors in order to catch up to frontier technology in the future. The effect of the interaction of returns to tertiary education with the technology gap is negative and significant. The mismatch between human capital and technology increases if the technology gap is high, and this adversely affects the change in productivity.

The relationship between HHI (market concentration rate) and the change in productivity is positive and significant, and therefore, as the market concentration rate increases, productivity increases more quickly.

If the market share of local producers is reduced and the competitiveness of producers decreases with the liberalisation of trade, the increase in costs of new technology could reduce productivity and lead to a backward slide. With the application of a new import policy, the best recommendation may be to support local producers who may lose their competitiveness with imports.

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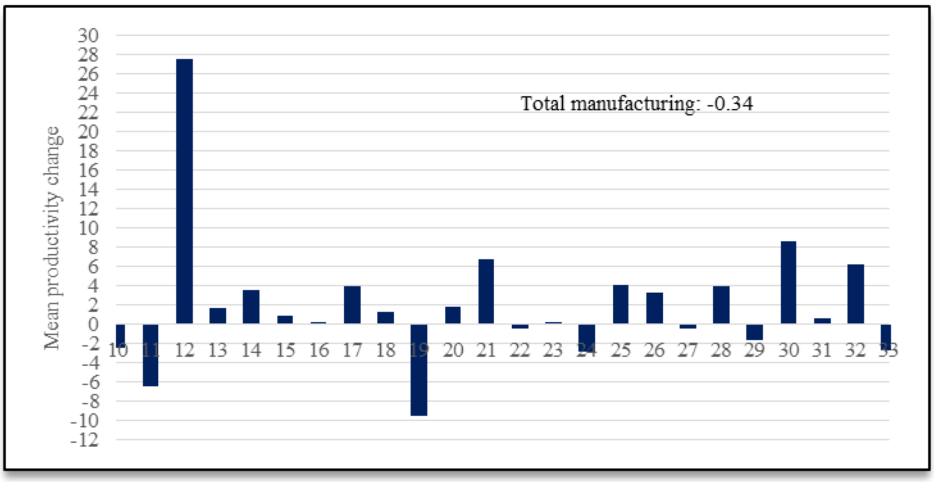
Appendix A: Technology Classification of Manufacturing Industries

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

Source: Eurostat (2020)

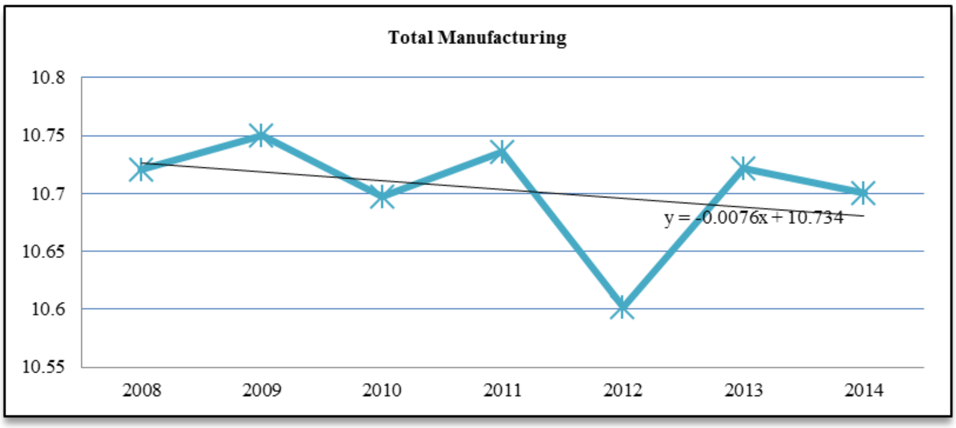
Appendix B: Labour Productivity by Groups of Sectors

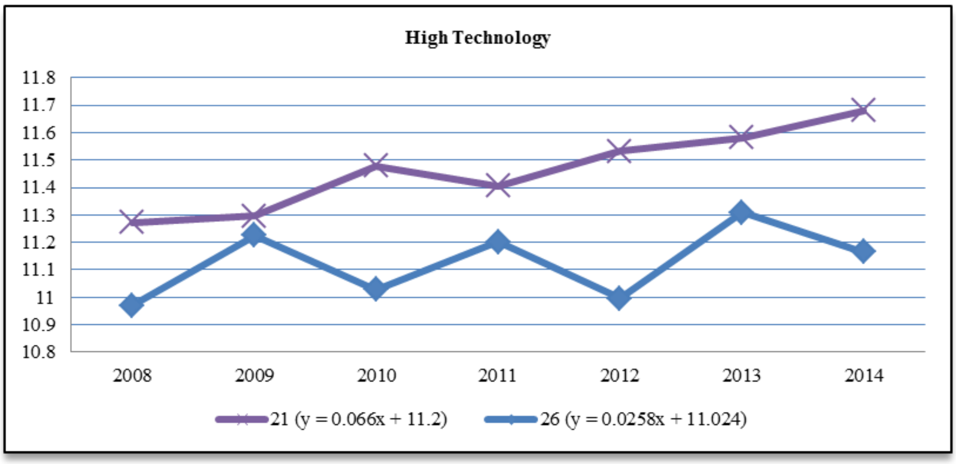
Figure B1: Average productivity change by sectors between 2009 and 2014

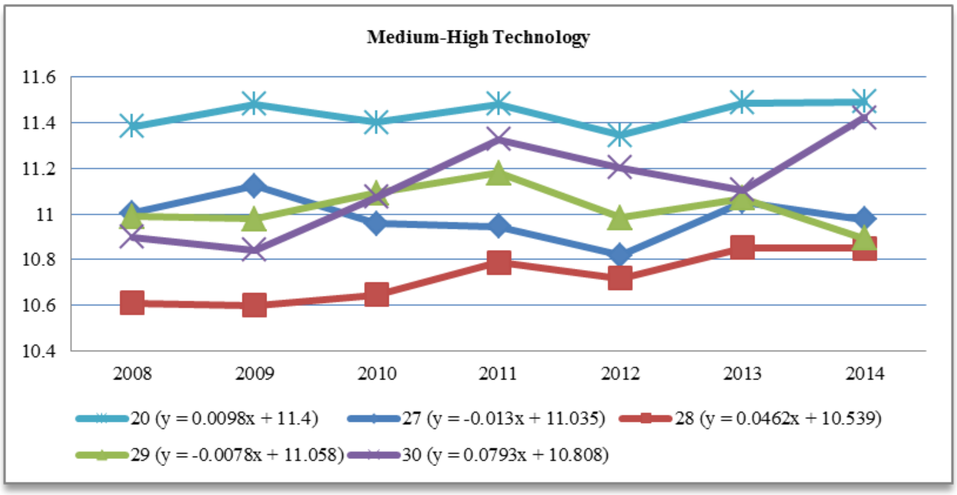


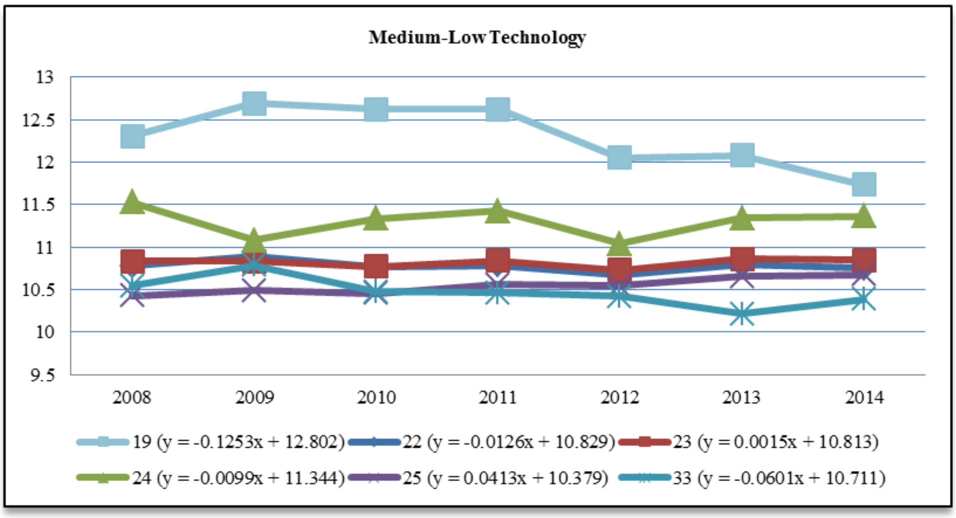
Source: Author’s own calculation from AISS data from TurkStat

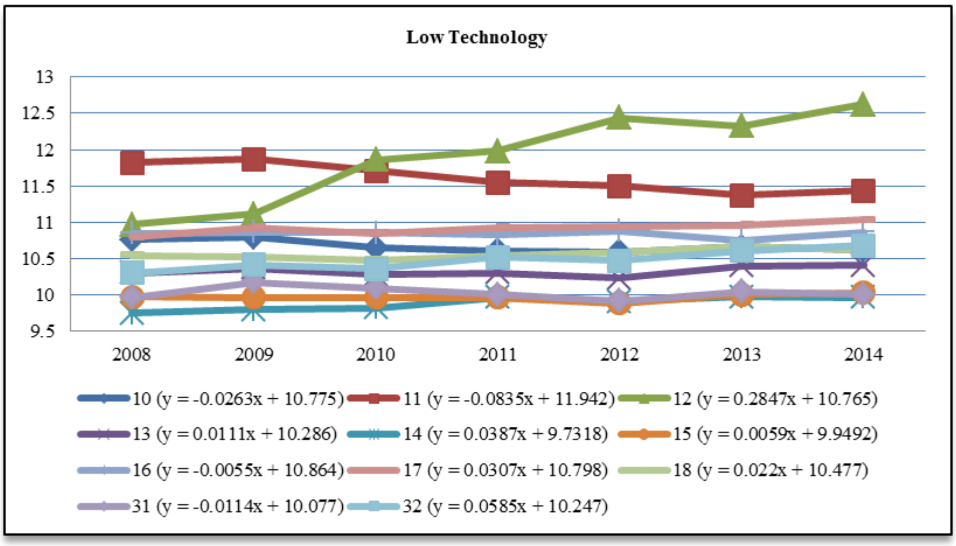
Figure B.2: Labour productivity by sectors, between 2008 and 2014, Ln (LP)








Medium-Low Technology
13
12.5
12
11.5
11
10.5
10
9.5
2008
2009
2010
2011
2012
2013
2014
19 (y = -0.1253x + 12.802)
22 (y = -0.0126x + 10.829)
23 (y = 0.0015x + 10.813)
24 (y = -0.0099x + 11.344)
25 (y = 0.0413x + 10.379)
33 (y = -0.0601x + 10.711)


Low Technology
13
12.5
12
11.5
11
10.5
10
9.5
2008
2009
2010
2011
2012
2013
2014
10 (y = -0.0263x + 10.775)
11 (y = -0.0835x + 11.942)
12 (y = 0.2847x + 10.765)
13 (y = 0.0111x + 10.286)
14 (y = 0.0387x + 9.7318)
15 (y = 0.0059x + 9.9492)
16 (y = -0.0055x + 10.864)
17 (y = 0.0307x + 10.798)
18 (y = 0.022x + 10.477)
31 (y = -0.0114x + 10.077)
32 (y = 0.0585x + 10.247)

Appendix C: Export and Import Shares by Countries

Table C.1: Export and import shares by countries in 2014, %

Exports				
	EU28		World	
Sectors	**Share**	**Countries with highest share**	**Share**	**Countries with highest share**
10	32.94	Germany, Italy...	41.29	Iraq, Germany, Italy, Syria
11	21.26	Germany, UK…	51.09	Iraq, Northern Cyprus, Germany, Syria
12	6.7	Germany, Netherlands…	53.74	Iran, Bahrain, Iraq, Israel
13	44.77	Germany, Italy…	28.93	Germany, Italy, Russian Fed, US
14	76.08	Germany, UK…	50.01	Germany, UK, Spain, France
15	34.28	Italy, Germany…	36.96	Russian Fed, Italy, Iraq, Germany
16	7.85	Bulgaria, Germany…	52.52	Iran, Iraq, Azerbaijan, Turkmenistan
17	22.96	UK, Bulgaria…	32.26	Iraq, UK, Iran, Azerbaijan
18	43.16	Germany, Poland…	51.32	Germany, Azerbaijan, Poland, Iraq
19	32.22	Malta, Spain…	44.9	Egypt, Malta, UAE, Northern Cyprus
20	31.73	Italy, Germany…	23.45	Italy, Iraq, Iran, China
21	18.92	Germany, UK…	32.64	South Korea, Switzerland, Germany, Iraq
22	44.79	Germany, Italy…	26.76	Germany, Iraq, Italy, UK
23	28.94	Germany, UK…	28.62	US, Iraq, Germany, UK
24	22.88	Germany, UK…	37.42	Switzerland, US, UAE, Iraq
25	36.7	Germany, UK…	29.99	Germany, Iraq, Turkmenistan, UK
26	68.76	Germany, UK…	46.12	Germany, UK, France, Poland
27	46.49	UK, Germany…	35.47	UK, Germany, Iraq, France
28	31.54	Germany, Italy…	25.27	Germany, Russian Fed, Iraq, US
29	75.85	Germany, UK…	47.75	Germany, UK, France, Italy
30	31.2	Italy, Germany…	41.56	US, Norway, Marshall Islands, Italy
31	23.61	Germany, France…	43.64	Iraq, Libya, Azerbaijan, Germany
32	13.75	Germany, Belgium…	58.2	UAE, Iran, Iraq, Syria
Imports				
	EU28		World	
Sectors	**Share**	**Countries with highest share**	**Share**	**Countries with highest share**
10	27.5	Germany, Netherlands…	43.4	Russian Fed., Indonesia, Ukraine, US
11	59.88	UK, Austria…	60.69	US, UK, Austria, Russian Federation
12	34.08	Germany, Netherlands…	54.06	Brazil, Germany, Netherlands, US
13	23.23	Italy, Germany…	50.93	China, Indonesia, Italy, India
14	15.67	Italy, Spain…	65.57	China, Bangladesh, Italy, India
15	23.12	Italy, Spain…	73.85	China, Italy, Vietnam, Indonesia
16	45.4	Romania, Bulgaria…	47.38	Russian Fed., Romania, Bulgaria, Ukraine
17	58.44	Germany, Finland…	44.13	Germany, US, Finland, China
18	55.86	Germany, Hungary…	50.31	Germany, China, US, Hungary
19	33.64	Greece, Italy…	65.69	Russian Fed., Greece, India, Israel
20	43.32	Germany, Belgium…	32.36	Germany, China, Saudi Arabia, South Korea
21	65.53	Germany, France...	49.82	Germany, US, France, Switzerland
22	55.57	Germany, Italy…	47.41	Germany, China, Italy, South Korea
23	44.39	Germany, Italy…	54.59	China, Germany, Italy, India
24	29.24	Germany, Spain…	40.11	Russian Fed., Switzerland, UAE, Ukraine
25	49.83	Germany, Italy…	55.63	China, Germany, Italy, South Korea
26	21.35	Germany, France...	67.28	China, South Korea, Germany, Vietnam
27	51.88	Germany, Italy…	57.99	China, Germany, Italy, France
28	59.28	Germany, Italy…	56.41	Germany, China, Italy, Japan
29	81.04	Germany, UK…	53.15	Germany, UK, Spain, Poland
30	42.63	France, Spain…	75.24	US, France, China, Spain
31	49.22	Italy, Germany….	62.4	China, Italy, Germany, Poland
32	30.16	Italy, Germany….	63.43	China, US, Italy, Germany

Source: Author's own calculation from Foreign Trade dataset from TurkStat

Appendix D: Export and Import Intensities by Groups of Sectors

Table D.1: Export and import intensities by sectors, between 2008 and 2014

	Export Intensity		Import Penetration		Export-Import Ratios	
Sector	**2008**	**2014**	**2008**	**2014**	**2008**	**2014**
Total Man.	32.75	32.1	36.7	37.48	0.84	0.79
High Technology						
21	8.74	18.27	48.92	55.29	0.1	0.18
26	45.53	49.98	76.19	84.42	0.26	0.18
Medium-High Technology						
20	24.5	30.12	61.32	64.66	0.2	0.24
27	34.59	41.22	34.9	37.24	0.99	1.18
28	39.12	37.5	62.5	60.26	0.39	0.4
29	58.45	50.85	53.03	49.79	1.25	1.04
30	80.16	60.61	79.29	72.82	1.06	0.57
Medium-Low Technology						
19	31.94	29.05	46.95	57.22	0.53	0.31
22	25.82	30.27	20.02	22.59	1.39	1.49
23	20.23	15.33	8.34	8.36	2.79	1.98
24	43.81	31.99	47.33	42.74	0.87	0.63
25	30.62	31.87	22.98	21.76	1.48	1.68
Low Technology						
10	14.29	17.73	8.47	9.21	1.8	2.12
11	4.93	7.32	5.95	9.58	0.82	0.75
12	10.7	21.78	14.08	21.89	0.73	0.99
13	31.85	31.29	19.33	17.09	1.95	2.21
14	54.8	58.22	16.09	20.28	6.32	5.48
15	19.73	29.51	36.22	37.12	0.43	0.71
16	10.45	14.08	16.47	20.2	0.59	0.65
17	16.29	18.73	35.47	30.87	0.35	0.52
18	0.39	0.52	1.3	1.35	0.29	0.38
31	16.83	23.88	10.35	10.64	1.75	2.63
32	37.33	106.37	44.75	108.75	0.74	1.34

Source: Author's own calculations

Appendix E: Other Estimation Results

Table E.1: Correlations between variables

	$\Delta ln(LP)$	*TG(-1)*	*RDINT*	*HC*	*IMPEN*	*EXINT*	*FORSH*	*TANGINV*	*HHI*
$\Delta ln(LP)$	1								
TG(-1)	0.28* (0.00)	1							
RDINT	0.10 (0.25)	-0.02 (0.98)	1						
HC	-0.06 (0.52)	-0.25* (0.00)	0.29* (0.00)	1					
IMPEN	0.08 (0.34)	0.02 (0.84)	0.62* (0.00)	0.12 (0.17)	1				
EXINT	0.03 (0.71)	0.30* (0.00)	0.42* (0.00)	-0.08 (0.37)	0.68* (0.00)	1			
FORSH	0.01 (0.89)	-0.13 (0.13)	0.25* (0.00)	0.40* (0.00)	0.29* (0.00)	0.09 (0.31)	1		
TANGINV	-0.04 (0.67)	-0.09 (0.30)	0.07 (0.45)	0.03 (0.78)	-0.14 (0.11)	-0.09 (0.30)	-0.03 (0.74)	1	
HHI	-0.15 (0.08)	-0.47* (0.00)	0.05 (0.54)	0.02 (0.85)	0.24* (0.01)	-0.01 (0.95)	-0.11 (0.20)	-0.34* (0.00)	1

Note: p-values in parentheses * $p<0.05$.

Table E.2: Productivity change, exports lagged one year and interaction effects, fixed-effects estimations with Driscoll-Kraay standard errors

Dependent Variable: $\Delta ln\ (LP)$								
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
TG(-1)	0.53*** (0.11)	0.46*** (0.11)	0.61*** (0.09)	0.61** (0.21)	0.60** (0.20)	0.57** (0.22)	0.44** (0.15)	0.59 (0.37)
RDINT(-1)	8.10 (4.23)	2.90 (7.91)	8.18 (4.38)	8.18 (4.45)	8.37 (4.21)	8.59* (4.24)	8.24 (4.14)	0.52 (12.79)
HC(-1)	-0.01 (0.02)	-0.01 (0.02)	0.01 (0.02)	0.01 (0.02)	0.01 (0.02)	0.01 (0.01)	-0.01 (0.02)	-0.01 (0.02)
IMPEN (-1)	-0.86* (0.36)	-0.84* (0.34)	-0.94** (0.36)	-0.94 (0.55)	-0.67 (0.83)	-0.76 (0.83)	-0.87* (0.35)	-0.32 (1.39)
EXINT(-1)	1.40*** (0.33)	1.38*** (0.32)	1.44*** (0.31)	1.44*** (0.34)	0.95 (0.76)	1.20 (0.70)	1.12* (0.55)	1.10 (0.69)
FORSH	0.49 (0.29)	0.47 (0.28)	0.57 (0.33)	0.57 (0.34)	0.58 (0.32)	0.30 (0.38)	0.51 (0.27)	0.48 (0.34)
TANGINV	-0.65 (0.75)	-0.77 (0.79)	-0.65 (0.75)	-0.65 (0.76)	-0.61 (0.74)	-0.71 (0.83)	-0.63 (0.72)	-0.78 (0.79)
HHI	7.65*** (1.30)	7.36*** (1.58)	7.78*** (1.27)	7.78*** (1.38)	8.08*** (1.54)	8.06*** (1.61)	7.75*** (1.33)	7.55*** (1.66)
TG*RDINT		6.01 (5.52)						8.76 (10.58)
TG*HC			-0.07** (0.02)	-0.07** (0.02)	-0.07** (0.02)	-0.08** (0.02)		
TG*IMPEN				0.002 (0.31)	-0.32 (0.68)	-0.26 (0.68)		-0.56 (1.24)
TG*EXINT					0.51 (0.76)	0.33 (0.75)	0.28 (0.35)	0.33 (0.80)
TG*FORSH						0.34 (0.26)		-0.05 (0.33)
Constant	-1.28*** (0.27)	-1.19** (0.33)	-1.32*** (0.25)	-1.32** (0.38)	-1.34** (0.40)	-1.31** (0.43)	-1.21** (0.35)	-1.33* (0.56)
R-squared	0.4302	0.4381	0.4464	0.4464	0.4485	0.4511	0.4317	0.4412
F Stat	199.55	95.68	499.31	180.65	233.13	211.08	116.35	123.08
Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	132	132	132	132	132	132	132	132
Sectors	22	22	22	22	22	22	22	22

Note: Random effects are rejected and fixed effects results are presented above. Autocorrelation, cross-sectional dependency, and heteroscedasticity problems in the data were tested for; therefore, Driscoll-Kraay estimators were found to be suitable for the model. Driscoll-Kraay standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$