The Effects of R&D and High Technology Exports on Economic Growth: A Comparative Cointegration Analysis for Turkey and South Korea

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Abstract

The importance of technology and research and development (R&D) on economic development through international trade has been discussed in many studies. However, the empirical studies focusing on the role of high technology exports has been limited. The study aims at filling this gap by evaluating the relationship between high technology exports and GDP per capita levels with structural unit root tests and cointegration methodologies for Turkey and South Korea for the 1989-2014 period. The following hypothesis is evaluated: by increasing high technology manufactured goods' exports, countries could increase their GDP per capita which also requires increased R&D that translates itself as high technology manufactured exports. The empirical methodology is as follows: both GDP per capita and high-tech exports variables are tested with traditional ADF, PP unit root and KPSS stationarity tests. The series are further evaluated with Zivot-Andrews single break and Lee-Strazicich two break unit root tests. The structural break tests are necessary; it is well-known that structural breaks lead to biased results in the traditional unit root and additionally in the cointegration tests. Lastly, both variables are tested for cointegration with Engle-Granger and Johansen tests by incorporating the break dates as exogenous dummy variables. The estimated models are further checked for parameter instability with CUSUM type tests. The results obtained for Turkey and South Korea are slightly different: *i.* both variables are cointegrated for both countries; ii. For South Korea, the positive impact of high-tech exports on GDP cannot be rejected in the long and short run; *ii.* This conclusion cannot be obtained for Turkey, *iii.* the parameter estimates for Turkey hint a limited positive effect of high tech exports in the short-run only. The results suggest that, in the future, Turkey should increase the investments in human capital and R&D directed to high tech exports to which could accelerate the economic growth.

1 Introduction

One point that cannot be overlooked regarding the importance of technological achievements on economic development is that, technological innovations and research and development play a crucial role not only in industrial and economic development, but additionally, the effects of creating heterogeneous products through technology in international trade cannot be disregarded. The technologically improved products are well known to create comparative advantage in exports. This type of an advantage could result from the increasing returns and endogenous technological progress which in turn affect the standards of living (Frankel & Romer, 1999). By shifting the percentage of manufactured exports from low technology to high technology products could result in comparatively value-added products which are subject to a type of monopolistic competition instead of products being traded in perfectly competitive products. Recent experiences of many Asian Economies in 1990's and additionally the experience of South Korea has been discussed to provide an example of such an economic growth strategy (Westphal, 1990). Within this perspective, the study aims at evaluating and comparing the long-run and short-run effects of high technology exports on economic development in Turkey and South Korea. It should also be kept in mind that, though the increase in export revenues from the high-technology products are expected to create significant contribution to economic growth, both of these countries have comparatively different characteristics and policies followed in 1960's and in the post 1980's, the liberalization period. Therefore, the study is restricted to evaluate the roles of high technology exports in economic development in terms of GDP per capita levels only and the role of R&D levels in the determination of high technology exports will also be evaluated. Nevertheless, both countries implemented important industrial policies in 1960's, their performances in terms of per capita GDP and high technology products and their share in manufactured exports had been considerably different.

As stated by Helleiner, industrialization has played an important role in the national modernization policies of all developing countries. With the increasing role of industry in the economies of these developing countries, trade in manufacturing has also become an important channel for strengthening their position in the world economy (Helleiner, 2002, xi). Salvatore notes that, from 1950s to 1970s, most developing nations generally opted for a policy of import substitution to industrialize by protecting their infant industries rather than continuing to specialize in the production of primary commodities, as defined by traditional trade theory. However, the import substitution policy led to very inefficient domestic industries and very high prices for domestic consumers; then, starting in the 1980s, many developing nations began to liberalize trade and adopt an outward orientation. These, in turn, resulted in a much higher degree of openness, as measured by the sum of exports plus imports as a ratio of GDP, a sharp increase in the ratio of manufactures in total exports (Salvatore, 2013, 347-348). However, it is also discussed in recent studies that, an export-led-growth strategy could be achieved with international trade if the traded goods are coupled with R&D being directed to technological progress that results in high-technology exports which are highly value added and could benefit the countries in terms of GDP per capita levels (Van den Berg, 2015).

Turkey and South Korea represent two different cases of export-oriented growth. The export-led industrialization policy of Turkey is realized by the shift of industrial capacity toward international markets via a significant contraction of real wages, excessive export subsidies, and real devaluations. Adjustment in South Korea, in contrast to Turkey, based on a nationalized financial sector, dual interest rates, rationing in the credit markets as a means of subsidizing exports, controls over foreign direct investments shaped the business environment until the mid or late 1980s. As a result, South Korea, which started with a much lower per capita GDP from 1960’s, reached a comparable level already as of 1978, and since then has reached much higher levels (Onaran and Stockhammer, 2005, 73-74).

This study examines the relationship between research and development (R&D) expenditures and high technology exports and growth in Turkey and South Korea during the period 1989-2014. The empirical research in this field is scarce, most probably resulting from the availability of data: as will be shown, the R&D data is limited to 1996-2013 period, while the high technology exports data is comparatively large while still being limited to the 1989-2014 period. Therefore, due to availability of data, the analysis in the study aims at evaluating the relationship between the high technology manufactured exports and economic development for the 1989-2014 period. The sections of the study are as follows. The economic literature is given in Section 2. The comparative analysis of South Korea and Turkey is given in Section 3. The econometrics literature review is given in Section 4. The econometric evaluation and results are given in Section 5. Conclusion is given in Section 6.

2 Theoretical Framework

The classical economists of the eighteenth and nineteenth centuries argued that technological change and capital accumulation were the engines of growth. In 1930s, Joseph Schumpeter, founder of modern growth theory, emphasized the importance of innovation as stimuli to economic growth (Trott, 2012, 7).

The Schumpeterian model of technological progress supports the hypothesis that international trade stimulates technological progress and, therefore, economic growth because it makes innovations available to more people in more countries, and increases the world’s effective resources that can be allocated to innovative activities. Furthermore, Levine and Renelt (1992), Edwards (1998), Frankel and Romer (1999), Wacziarg (2001), and Easterly and Levine (2001) found evidence showing that international trade’s effect on economic growth operates through technological progress (Van den Berg, 2015, 174).

Robert Solow, who was a student of Schumpeter, advanced his professor’s theories in such a way that, in the absence of technological progress, factor accumulation is subject to diminishing returns and an economy sooner or later settles at a steady state where economic growth ceases (Van den Berg, 2015, 111).

In 1967, Gruber, Mehta, and Vernon found a strong correlation between expenditures on research and development and export performance. The authors took expenditures on research and development as a proxy for the temporary comparative advantage that firms and nations acquire in new products and new production processes (Salvatore, 2013, 173).

The new theory of endogenous economic growth starting with Romer (1986) and Lucas (1988) postulated that international trade will speed up the rate of economic growth and development in the long run especially by allowing developing nations to absorb the technology developed in advanced nations and increasing the benefits that flow from research and development (Salvatore, 2013, 336).

South Korea is considered to be one of the good examples of countries providing its economic growth through international trade. Combined with a rapid slowing down in population growth, this growth resulted in important increases in per capita income through rising wages and rapid job creation. As a result, since the early 1960s, this country had averaged between 6% and 8% growth per year (Jaffe, 2010, 51). Chau underlined that the outstanding economic growth of Korea has resulted from the promotion of merchandise exports. Korea established its export-oriented light industry by using cheap labor and thus low wages. But when the labor became more expensive compared to other developing countries, their industrial composition shifted to heavy and chemical industries in 1970s. When these industries started to become competitive in world market after mid-1980s, they began to upgrade their technology to produce and develop sophisticated high-tech products (Chau, 2001, 140). Many researchers underline the importance of state intervention to promote economic development in South Korea. Westphal argued that Korea's government has selectively intervened to affect the allocation of resources among industrial activities and has also used policies such as taxes and subsidies, credit rationing, licensing, and the creation of public enterprises (Westphal, 1990, 41). According to Amsden, industrial expansion of this country could be explained as a good co-integration of market principles and of the institutions financially supporting them. Another reason why South Korea appear to have industrialized rapidly is that this country has invested relatively heavily in formal education of the workforce and the apprenticeship of firms to foreign technical assistants (Amsden, 1989).

3 A Comparative Analysis of Population, R&D, Sectoral Development, High-Tech Exports and Economic Performance in South Korea and Turkey

In 1962, the population sizes of Turkey (28.909.985) and South Korea (26.513.030) were close to each other. In South Korea, with a rapid slowing down in population growth from 1970s on, the population size reached to 50.423.955 in 2014 whereas Turkey's population size has made a big jump to reach to 75.932.348.

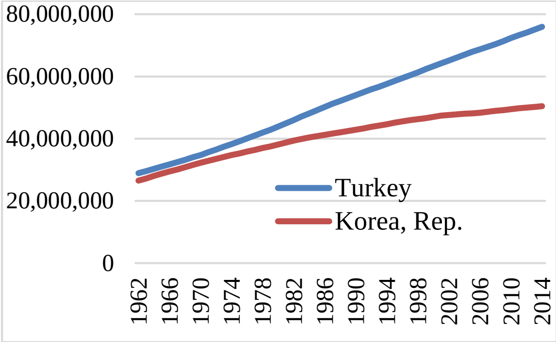


Figure 1. Evolution of Population in South Korea and Turkey (1962-2014) ***Source****: World Bank, World Development Indicators*

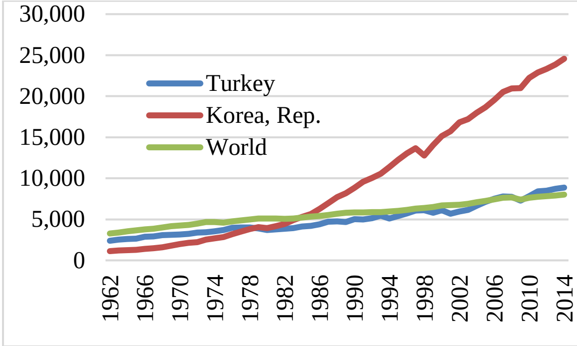


Figure 2. Per Capita GDP in South Korea, Turkey and The World (1962-2014) ***Source****: World Bank, World Development Indicators*

As the Figure 2 suggests, in 1962, per capita GDP in Turkey (US$2.387) is 2,1times that of S. Korea's at US$1.123 (world average is US$3.275). However, beginning with 1980s, South Korea has made a big attack; as of 2014 Turkey's GDP per capita is US$8.865 whereas S. Korea's GDP is 2,7 times that of Turkey's at US$24.566 (world average is US$8.011).

Both Turkey and South Korea started as resource-poor, agrarian economy. As the Figures 3 and 4 indicate, agricultural and services sectors were dominant in these countries during 1960s. The share of industry in the whole economy was close to each other in Turkey (19.9%) and South Korea (21.3%) in 1965. A rapid industrialization process took place in South Korea as of 1970s as a result of which the share of industrial sector in GDP reached as high as 39% in 1990s. In Turkey, the share of industry went to 27.1 percent in 2014 while this share made relatively a big jump to reach to 38.2 percent in South Korea. For Turkey the highest rate recorded for the share of industrial sector is 35% achieved in 1999. Agriculture's share shrank to 8.0% and 2.3% in Turkey and in South Korea respectively. As noted by Chau, South Korea's economic development in this period was fueled by an intensive increase in factor input and rapid expansion of exports after which, within three decades, the economy was transformed from a backward poor agrarian economy into an industrial economy (Chau, 2001, 125).

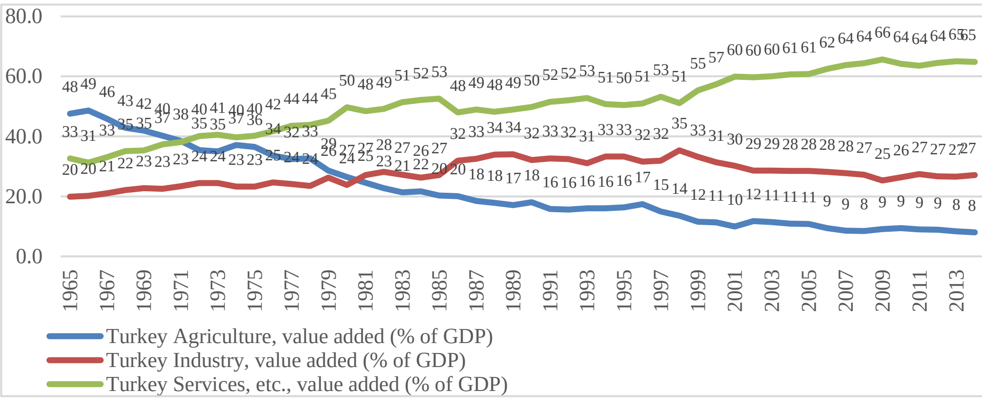


Figure 3. *Evolution of Production in Turkey (1965-2014)* ***Source:*** *World Bank, World Development Indicators*

Industrial development in South Korea and Turkey started out with developing labor intensive light manufacturing industries. But, in South Korea, as early as mid-1973, the aim of state policy was to develop heavy and chemical industries producing for exports (Arslanhan and Kutsal, 2010a). For this purpose, six industries (industrial machinery, shipbuilding, electronics, steel, petrochemical and non-ferrous metal) were targeted for promotion. By 1990, products from these industries accounted for 40% of total exports (Chau, 2001, 123).

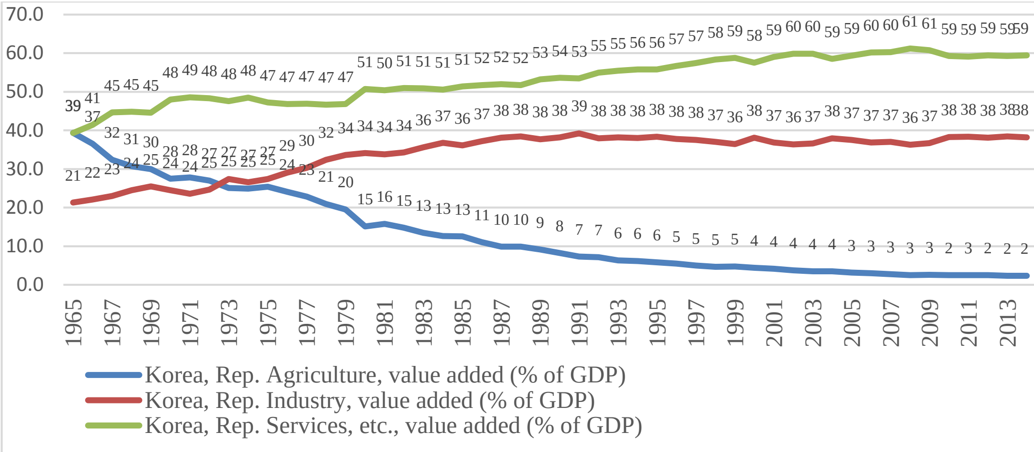


Figure 4. *Evolution of Sectoral Production in South Korea (1965-2014)* ***Source:*** *World Bank, World Development Indicators*

From 1990s to early 2000, the share of electrical and electronics goods increased from 15 to 25 % in South Korea. Over the same period the gap between the share of the said sectors and low-tech labor intensive food, beverages and textiles sector, which dropped below 5%, widened significantly and the dominance of the sectors requiring high technology gained importance. This process proves the dominance of innovation, Information and Communication Technologies (ICT) and R&D activities in industrial development in the context of the 'Innovation Process' in South Korea (Arslanhan and Kutsal, 2010, 4).

Examination of Turkey and South Korea's share of high technology exports in manufactured exports for the period 1989 and 2014 indicates that South Korea enabled rapid switch to high technology whereas Turkey went through a direction towards medium and low technology sectors (Figure 5).

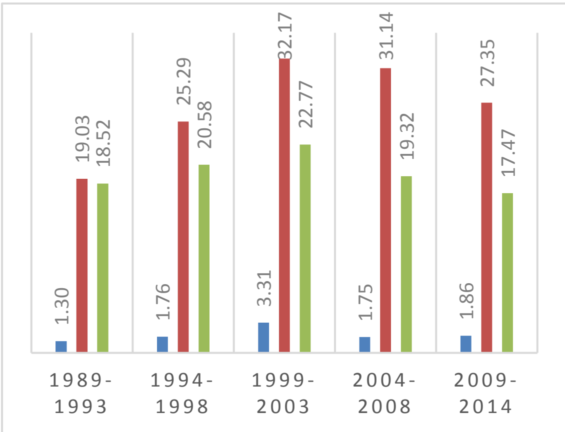


Figure 5. *The % of High-Technology Exports in Manufactured Exports, 5 Year Averages, 1989-2014*

Notes. *Turkey (blue), South Korea (red), World (green).*

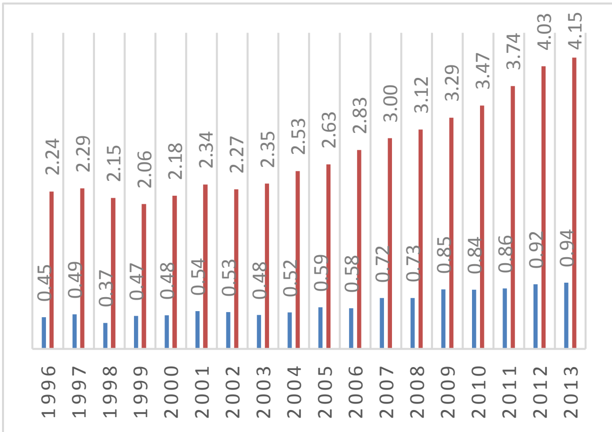


Figure 6. *Research and Development Expenditures, % of GDP, 1996-2014*

Source*: World Bank, World Development Indicators*

As the Figure 6 clearly indicates, R&D expenditures constitutes relatively an important part in South Korea's GDP when compared to Turkey. R&D increased its share of GDP from 2,24 % to 4,15 % in 1996-2013 in South Korea whereas this share moved from 0,45 % to 0,94 % in Turkey. The biggest contribution to rapid economic growth in South Korea was made through the development of the R&D system. As a response to incentives and increasing competition in the international market, the number of corporate R&D laboratories and patent registrations rapidly increased (Chau, 2001, 146). In 1960s, the Korean government created a Bureau of Technologies which was upgraded into the full-fledged Ministry of Science and Technology in 1967. Furthermore, Economic Planning Board created in 1962 played a central role in Korea's economic planning, national budgeting, foreign capital management and statistics (Chau, 2001, 214-218). With the help of the Heavy and Chemical Industry (HCI) policies, the HCI product group has performed well, in the sense that its market share in Korea's total exports increased consistently and sharply. Some of the projects promoted by the HCI policies have turned a few Korean companies into big multinational corporations (Chau, 2001, 23). For instance, Korean transnational producer, Hyundai, which had been dependent for its early development on close technological and marketing relationships with US and Japanese firms, was the world's fourth largest producer in terms of market share in automobile manufacturing (OICA, 2015).

4 Empirical Literature Review

Our research showed that though the relationship between economic development and exports has been investigated empirically in an important amount of studies, the empirical studies focusing on R&D and economic development is comparatively limited. Further, as of our search conducted on these three variables showed that, the role of high technology manufactured export products on economic growth has not been investigated. Therefore, our study will provide a pioneering analysis on the role of high-tech export products on economic development. As a result, the literature review below will focus on the literature focusing on exports and economic growth and R&D and economic growth relations.

The empirical literature on exports and economic development began to be more widely discussed among researchers in recent years. Economists performed a variety of statistical tests to prove or disprove the existence of a relationship between research and development, human capital, innovations, exports and economic growth. If an overlook is provided, the results of these studies largely support the hypothesis that, countries investing in research and development provide their residents with higher incomes and higher rates of economic growth. Xu proved that in a sample of 32 economies, the export-led model is supported by 17 economies and is strongly supported by 9 economies (Xu, 1996, 172-184). Bayoumi, Coe, and Helpman (1999) estimated that if all developed countries increase their R&D expenditures by an amount equal to one-half of one percent of their GDPs, all industrial countries would raise their output after 80 years by nearly 20% and developing countries by almost 15%. Evenson and Singh (1997) tested for technology spillovers in 11 Asian economies and confirmed that domestic institutions and education are significant determinants of technology inflows. Technology spillovers have been small in the South Asian economies of Bangladesh, India, Nepal, Pakistan, and Sri Lanka compared to the fast-growing East Asian economies. The second group of countries, invested more in education, improved their institutions so that they were more favorable to investment and innovation, and opened their economies more widely to trade (Van den Berg, 2015, 240-241).

Kılıç, Bayar and Özekicioğlu examined the relationship between research and development expenditures and high technology exports in G-8 countries during the period 1996-2011 by using panel data analysis. They found that research and development expenditures and real effective exchange rate had positive impact on high technology exports. Moreover, they emphasized that there was bidirectional causality between research and development expenditures and high technology exports and between research and development expenditures and real effective exchange rate and unidirectional causality from high technology exports to real effective exchange rate (Kılıç et. al., 2014).

Göçer analyzed the effects of research and development expenditures on high technology exports, information-communication technology exports, total exports and economic growth for 11 developing Asian countries by using data of 1996-2012 period with panel data analysis. As a result of the analysis, it has been determined that an increase by 1% in R&D expenditures raised the high technology export by 6.5%, the information-communication technology exports by 0.6% and the economic growth by 0.43% (Göçer, 2013, 215).

Our study focuses on the role of high-tech product exports on economic growth. One reason of this approach is that we focus on providing a comparative analysis of South Korea and Turkey, therefore, we fail to adopt a panel regression approach as done by the above mentioned literature. Further, the study will aim on evaluation of long run and short run effects of high-tech exports on economic growth. Therefore, the study will focus on cointegration methodology of Engle-Granger (1987) and structural break unit root tests to determine the break dates, of high tech exports and economic development. It should be noted that, the R&D data is very limited and reported largely for the post 1996 period in institutions such as the World Bank. Similarly, the data for high tech exports could be obtained for a comparatively larger period starting from 1989. Within our approach, we make a generalization that high-tech exports could be considered as a proxy or as an indirect product of R&D itself. It should be noted that the R&D is an important result of the long run development strategies of the economies of today. These strategies include investment in education, science, technology, health and research among many other factors of human development. This type of strategy would mimic the endogenous growth models. However, the technological export-led growth strategy should be considered as being under the influence of development strategies such as the unbalanced and balanced growth models in addition to important critics directed towards the relationship between the exports and the imports goods, the type of products traded and importance of power through trade which result from the supply effect and influence effect of trade (readers are referred to Hirshman, 1969; Singer, 1958). Further, underdeveloped countries could be under the influence of a poverty-cycle that results in very limited investment on human capital (Nurkse, 1966). However, the aim of the study is restricted in terms of focus on the investigation of possibly cointegrated long-run relations between high-tech exports and economic performances to provide a comparative analysis for Turkey and South Korea. Therefore, a throughout analysis of the role of R&D, education, human capital, and many important external factors as discussed in orthodox and heterodox development approaches were left for the future studies.

It should be noted that, our literature search resulted in no studies focusing on the effects of high technology manufactured product exports on economic growth within a time series context, we believe that this was largely due to the availability of data. To overcome this difficulty, few studies followed panel regression approaches to increase the sample size through pooling of the dataset for homogeneous characteristics as noted above.

5 Data and Empirical Results

The paper aims at investigating the relationships between high-technology manufactured exports, economic development and R&D expenditures with cointegration techniques. Within this purpose, the Engle and Granger (1987) two-stage cointegration methodology will be analyzed. The cointegration approach is solely based on the common integration of the variables at the same level *d* and requiring variables following integrated of order d, I(d) processes. Therefore, the cointegration approach could be affected by possible structural breaks caused by factors including economic crises which in turn might hinder the reliability of traditional unit root tests. As a result, the econometric methodology also aims at investigating stationarity of data with Zivot-Andrews (1992) and Lee-Strazicich (2003) structural break unit root tests in addition to the traditional unit root tests.

5.1 Data

In this study, the GDP per capita, high-tech exports and R&D expenditures are taken from the World Development Indicators (WDI) 2015 database of the World Bank. The dataset for GDP per capita and the percentage of high-tech exports in total manufactured exports corresponds to 1989-2014 period, while the R&D expenditures in GDP corresponds to 1996-2013 period. Due to the sample size limitations of the R&D data, the analysis is conducted with the GDP per capita and high-tech exports data. Further, since high-tech exports are also considered as a proxy for R&D focusing on differentiation of the export product, this type of limitation could be considered as resulting from the availability of R&D data for a large span. In the analysis, the GDP per capita is denoted as y_t, which is given in constant 2005 US dollars. The % of high tech exports in total manufacturing exports is given in US dollars and is denoted as ht_t. All variables are subject to natural logarithms with the following transformation: $lht_t = \ln(ht_t)$, $ly_t = \ln(y_t)$. Additionally, the first differenced variables in natural logarithms are calculated as $\Delta lht_t = lht_t - lht_{t-1}$ and $\Delta ly_t = ly_t - ly_{t-1}$ which represent the yearly growth rates of the respected variables. The distributional characteristics of the analyzed variables are given in Table 1 below.

Variable:	Mean	Min.	Max.	Std.dev.	JB
$lht_{t,TR}$	0.61	-2.77E-05	1.57	0.36	6.87[0.03]
$lht_{t,SK}$	3.28	2.88	3.56	0.20	2.49[0.29]
$\Delta lht_{t,TR}$	0.004	-0.77	0.64	0.27	4.04[0.13]
$\Delta lht_{t,SK}$	0.02	-0.16	0.17	0.08	0.64[0.72]
$ly_{t,TR}$	8.77	8.45	9.09	0.20	1.77 [0.41]
$ly_{t,SK}$	9.65	9.00	10.11	0.33	1.74[0.42]
$\Delta ly_{t,TR}$	0.02	-0.07	0.08	0.05	3.36[0.19]
$\Delta ly_{t,SK}$	0.04	-0.07	0.09	0.03	22.01[0.00]

Table 1. *Descriptive Statistics for the Analyzed Variables of South Korea and Turkey*

The results in Table 1 show that the high technology exports in total exports has been comparatively larger in terms of their means South Korea if $lht_{t,SK}$ and $lht_{t,TR}$ variables are evaluated. If their growth rates are compared, the average of $\Delta lht_{t,SK}$, the growth rate of high tech exports has been yearly around 2% in South Korea, while the average of $\Delta lht_{t,TR}$ represent an average growth rate of high tech exports has been 0.4 %. If the economic growth rates are to be compared ($\Delta ly_{t,SK}$ and $\Delta ly_{t,TR}$) the GDP per capita growth rates in South Korea has been 4%; twice as large of that in Turkey. The results for the Jarque-Berra test statistics (JB) show that, normality of the series cannot be rejected at 5% significance level except for $lht_{t,TR}$ and $\Delta ly_{t,SK}$. However, the analysis of normality of the residuals should be checked especially for the residuals of the estimated regression models. Further, the dataset is subject to structural breaks as to be discussed in the next section.

5.2 Econometric Methodology

The econometric methodology followed in the study consists of several steps. At the first step, the stationary of high tech exports and GDP per capita levels is evaluated with traditional ADF and PP unit root tests. The KPSS stationarity test is known as having better properties for various types of data including time series following nonlinear processes of being subject to structural breaks. Further, it is well known that the results obtained with traditional unit root test might be altered if the evaluated time series contain structural breaks. Therefore, to test for an Engle & Granger (1987) type cointegration relation between the analyzed variables, the research should focus an initial analysis of structural breaks and unit roots testing in addition to the general approaches based on posterior, i.e. after estimation, instability tests of parameters with CUSUM, CUSUMSQ type tests.

5.2.1. Stationarity, Structural Breaks and Cointegration

As noted by Esteve et.al., (2013), linear cointegration tests might produce instability due to structural breaks and long run regressions may suffer instability. To overcome this difficulty, Arai & Kurozumi (2007) proposed residual-based tests in which the null hypothesis of cointegration with a structural break could be tested against the alternative of no cointegration. However, the high-tech exports data is rather limited in terms of sample size. Therefore, splitting the regression space into sub-samples might produce further misleading results.

The study aims at benefiting from Engle and Granger (1987) approach which to investigate the effects of high technology exports on economic performance. The cointegration approach requires the evaluation of stationarity of the analyzed time series. However, as noted above, structural breaks in time series could lead to a tendency towards the acceptance of the null hypothesis of unit root in ADF type unit root tests. Additionally, structural breaks not only effect the results of cointegration tests, the estimated models could also be subject to biased parameter estimates. Further, in addition to testing for structural breaks and unit roots before the estimation of the cointegration models, testing of parameter instability after the estimation of these models is a necessity.

As a result of the above mentioned limitations, the study aims at benefiting from structural break tests developed by Zivot & Andrews (1992) and Lee & Strazicich (2003). Zivot & Andrews (1992) and Perron (1997) tests are among the pioneering approaches however, these tests allow single structural break testing. Lee & Strazicich (2013) developed tests based on LM tests that allow testing of unit root hypothesis under two endogenous breaks. A common approach under variables that constitute structural breaks is to apply diagnostics tests including the CUSUM and CUSUMSQ. These tests are residual based tests and are applied after the estimation of the regressions for possible structural breaks. In the study, these type of post-estimation tests are also conducted for both the long-run and short-run regressions in cointegrating relationships. A similar approach is followed by Farhani et.al., (2014); Shahbaz, et.al., (2015) and Shahbaz, et.al., (2016) studies which utilized ARDL type cointegration analysis (Pesaran et.al., 2001). The traditional Engle & Granger (1987) cointegration technique requires common order of integration, i.e. both variables should be I(1) processes. Therefore, we propose the following methodology. The steps are specified in terms of the *specification*, *estimation* and *evaluation* ala Box-Jenkins (1986):

I. Specification. i. Evaluate the order of integration with ADF, PP and KPSS tests. KPSS test is known to produce more reliable results if the series is subject to structural breaks and nonlinearity. *ii.* For a cautionary measure, test the null hypothesis of unit root with ZA and LS tests to check for possible breaks. The breaks could result from factors such as the economic crises. Check if the ZA and LS tests also confirm that the series are I(1) after controlling for the structural breaks. *iii.* Create dummy variables corresponding to the estimated break/outlier dates, conduct the Engle-Granger test by including the crises dummy variables as exogenous variables and check for cointegration; this step could also be checked with Johansen cointegration test.

II. Estimation. Since the sample size is not large, the incorporation of possible structural breaks caused by factors such as the economic crises could be incorporated to the models with dummy variables. We avoid splitting the regression space into two or more sub-samples. The reason is the small size of the dataset. *i.* Estimate the model with OLS by following the Engle and Granger (1987) methodology; use crises dummy variables as exogenous variables; *ii.* The ZA and LS tests give information about the type of breaks: the breaks could be “impulse, i.e. in the intercept”, “trend, i.e. break in slope” or “both”. These correspond to three different modelling types, Model A, B and C (see LS, 2003). *iii.* Use the information obtained by the ZA and LS tests as initial information for the dates of breaks in the variables entering the regressions. The parameters of the dummy variables should be tested for significance after being estimated.

III. Evaluation. Diagnostic tests. *i.* general group of tests include: Ljung-Box Q test for autocorrelation, ARCH-LM heteroscedasticity test and RESET misspecification test; *ii.* test the parameter instability: CUSUM and CUSUMSQ. Check if the parameter stability is achieved and the models are capable of coping with parameter instability after the inclusion of the crises’ dummy variables. If parameter stability cannot be rejected, the estimation results could be considered for economic policy analysis. Note that cointegration is at the center of the analysis and the cointegration tests require a minimum sample size of 25 to obtain reliable results (See the User’s Guide, Eviews 9).

In the literature, due to sample size limits, many analyses are conducted even with lower number of observations, however, the small sample size properties of the structural break unit root tests are derived for larger sample sizes. For example, the application section of ZA (1992) include samples with T=61 and T=11 and the critical values of LS (2003) were derived for T=125. However, many studies in the literature had to be conducted for sample sizes due to availability of data (Farhani et al., 2014).

5.3 Empirical Results

At the first stage, the variables are tested with ADF and PP unit root and KPSS stationarity tests. The results are given in Table 2. Accordingly, the test results suggest that both GDP per capita and high-tech exports variables in natural logarithms for both countries are unit root processes and stationarity of the series cannot be accepted at conventional significance levels. Accordingly, the variables are first differenced and the first differenced series are tested for unit roots and stationarity. The overall results of the ADF, PP and KPSS tests suggest that all analyzed series are integrated of order 1; and they become stationary after being first differenced.

At the second stage, the variables are tested with Zivot-Andrews (1992, ZA) unit root test that allows one and the Lee & Strazicich (2003, LS) test that allows two endogenous structural breaks in unit roots testing. Due to availability of sample size, to minimize the loss of degrees of freedom, the lag length in these tests are selected with Schwarz information criteria (SIC). The results of structural break unit root tests are given in Table 3.

South Korea:				Turkey:			
Variable:	ADF	PP	KPSS	Variable:	ADF	PP	KPSS
lyk	-2.11 [0] (t+int)	-1.93 [5] (t+int)	1.40 (t+int)	$lytr$	-2.53 [0] (t+int)	-2.71 [1] (t+int)	1.17 (t+int)
Δlyk	-3.93** [3] (t+int)	-11.21*** [5] (t+int)	0.07*** (t+int)	$\Delta lytr$	-4.77*** [0] (t+int)	-5.51*** [1] (int)	0.03*** (t+int)
$lhtk$	-2.19 [0] (int)	-2.26 [4] (t+int)	2.41 (t+int)	$lhttr$	-2.07 [0] (int)	-2.04 [2] (int)	0.88 (int)
$\Delta lhtk$	-4.96*** [1] (t+int)	-5.92*** [1] (t+int)	0.04*** (t+int)	$\Delta lhttr$	-4.06*** [0] (int)	-4.51*** [1] (int)	0.07*** (int)

Table 2. *Traditional Unit Root Tests Results*

*Notes. *, **, *** denote significance at α=0.10, 0.05 and 0.01. The selected lag length is given in brackets. The assumptions of the unit root tests are reported in parentheses: t and int represent trend and intercept, respectively. The intercept (int) only Mckinnon (1996) critical values are -3.72, -2.98 and -2.63 at 1%, 5% and 10% significance levels. The intercept and trend Mckinnon (1996) critical values are -4.37, -3.60 and -3.24 at 1%, 5% and 10% significance levels. For the KPSS test, the default of Bartlett kernel is used for spectral estimation and the bandwidth is selected with Newey-West option. The critical values for the KPSS test are 0.74, 0.46 and 0.35 with allowing int and these values under the t+int assumption are 0.22, 0.15 and 0.12 at α=0.01, 0.05 and 0.10, respectively.*

The ZA and LS tests allow testing the structural break unit root under the null hypothesis. The critical values are reported from ZA (1992) and LS (2003). While both tests allow testing structural unit roots in analyzed series, in both tests, the break date is not predetermined by the researcher; therefore, both tests give preliminary information regarding the structural break dates. Further, the LS test allows two structural breaks while the ZA test allows single structural unit root testing. As noted in Section 4, structural breaks could result in biased parameter estimates in the traditional ADF and PP test results and could lead over acceptance of the null hypothesis of unit root in these tests (Esteve et.al, 2013). However, both the ZA and LS tests confirmed that all analyzed series in levels are I(1), integrated of order 1, processes and after taking first differences, (i.e. series denoted with Δ) they become stationary. Therefore, the ZA and LS tests confirmed that both high-tech exports and GDP per capita series are integrated of a common order, I(1). According to the ZA test results, the structural break dates are in years 2008-2009 (the Global Crisis) and 1998 (post effects of 1997 Asian Crisis) for South Korea and 2000-2001 Economic Crisis for Turkey.

	Zivot-Andrews Test		Lee-Strazicich Test Results			
	ZA-Stat:	Break date:	Model type:	LS-Stat:	Break Date 1	Break Date 2
lyk	-2.90 [0]	2009	A	-2.30 [1]	1998 (2.62**)	2008 (-0.92)
Δlyk	-5.14*** [3]	1998	C	-13.32*** [1]	1998 (-15.11***, 11.54***)	2002 (6.96***, -13.53***)
$lhtk$	-3.45 [0]	1999	C	-5.23 [1]	1998 (-2.35***,2.94***)	2007 (0.66, -5.02***)
$\Delta lhtk$	-6.51*** [1]	2001	C	-9.39*** [3]	1998 (-6.13***, 5.09***)	2008 (-3.58***, 3.33***)
$lytr$	-3.34 [0]	2002	C	-5.29 [2]	2001 (3.77***, -4.37***)	2007*** (-0.09, 3.12***)
$\Delta lytr$	-6.29*** [0]	2003	C	-7.41*** [5]	2001 (5.23***,-7.58***)	2008 (-7.02***, 7.10***)
$lhttr$	-3.58 [0]	2000	C	-4.95 [0]	1997 (-2.59***,4.93***)	2001 (-4.57***,4.37***)
$\Delta lhttr$	-6.36*** [0]	2001	C	-6.95*** [0]	1999 (0.47,-2.07**)	2003 (-0.41, 3.76***)

Table 3. *Structural Break Unit Root Test Results*

*Notes. *, **, *** denote significance at α=0.10, 0.05 and 0.01. The selected lag length is given in brackets. ZA (1992) critical values are-5.34, -4.93 and -4.58 at 1%, 5% and 10% significance levels. In LS (2003) test, Model A allows structural change in the intercept while, Model B and C allow in trend and in both the intercept and the trend. The LS test critical values for Model A are -4.545 -3.842 -3.504 for α=0.01, 0.05 and 0.10. The critical values also depend on λ, the position of break t in the sample, t/T. Here, the values for* $\lambda = 0.4$ *are reported to save space: -6.45, -5.67, -5.31 for α=0.01, 0.05 and 0.10. In the LS tests, the t1 and t2 statistics represent the t statistics of the level and slope break parameters which are given in parentheses under each break date.*

With allowing two structural breaks, the LS test gives more reliable results and the results: following the LS test results, for South Korea, the first break date is estimated as the year 1998 while the second break corresponds to 2007-2008 Global Crisis for 3 out of 4 tested variables. For Turkey, the LS tests suggest that the first break date coincides with 2001 Crisis and the post effects of 1997 Asian Crisis in 1998 while the second break corresponds to either 2001 Crisis or 1998 depending on the first estimated break. Overall, the LS test suggest inclusion of 2007-2008 Global Crisis and 2001 Economic Crisis as exogenous dummy variables in both the cointegration tests and into the regression models for Turkey.

The Engle-Granger and Johansen Cointegration test results are given in Table 4. The Engle-Granger test is conducted twice for each country, once by taking ly and once by taking lht as dependent variables. Further, both cointegration tests are conducted with allowing crises' dummies defined as exogenous variables in the testing process, D2001, D2008 and D1998 for Turkey and D1998 and D2008 for South Korea. Additionally, the test is conducted with linear trend assumption. The test results suggest that, for South Korea, cointegration cannot be rejected at 5% significance level and cointegration is accepted between the two variables if the GDP per capita (ly)

is taken as the dependent variable. The results show that while being both lht and ly are integrated of order (1), their linear combination is a stationary I(0) process integrated of order 0. According to the Engle-Granger test results for Turkey, at 5% significance level, if ly is taken as the dependent variable, the null hypothesis of no cointegration cannot be accepted and the results are in favor of cointegration between the ly and lht variables. As a result, for both countries, the two series are accepted to be cointegrated at 5% significance level.

Engle-Granger Cointegration Tests			
South Korea:		*Turkey:*	
Dependent variable:	tau-statistic:	Dependent variable:	tau-statistic:
ly	-4.23***	ly	-3.93**
lht	-3.36*	lht	-2.98
Johansen Cointegration Test Results: Turkey			
$Hypothesized\ no.of\ cointegrating\ vectors$	Eigenvalue	Trace Stat	Max.-Eigen Statistic
$none$	0.64	29.90***	24.42***
$at\ most\ 1$	0.20	5.48	5.48
Johansen Cointegration Test Results: South Korea			
$Hypothesized\ no.of\ cointegrating\ vectors$	*Eigenvalue*	*Trace Stat*	*Max.-Eigen Statistic*
$none$	0.66	31.59***	25.09***
$at\ most\ 1$	0.25	6.50	6.49

Table 4. *Cointegration Test Results*

*Notes. *, **, *** denote significance at α=0.10, 0.05 and 0.01. In both countries' Engle-Granger tests, intercept and linear trend is assumed in addition to dummy variables included for crises' years as exogenous variables. For Turkey, the cointegration equation deterministics are: constant, linear trend, D2001, D2008 and D1998 which correspond to the years 2001, 1998 and 2008. For S. Korea, deterministics are D1998 and D2008 in addition to the intercept and the deterministic trend. For the Johansen tests, for both countries, deterministic trend in the cointegration equation is assumed in addition to the above-mentioned dummy variables. In the Engle-Granger test, the critical values are: -4.39, -3.61 and -3.24 for 1%,5% and 10% significance levels.*

The Johansen cointegration tests are given in the second part of the Table. In the Johansen cointegration test, similar to the Engle-Granger test, deterministic trend is assumed in the cointegration relation. Additionally, the dummy variables included as exogenous variables are D2001, D2008 and D1998 for Turkey; and, D2008 and D1998 for South Korea. Both trace and maximum eigen statistics are statistically larger than the critical values and the results suggest acceptance of 1 cointegrating vector for the variables. Both Engle-Granger and Johansen tests suggest that ly and lht are cointegrated at conventional significance levels and a long-run relation between high-tech exports and GDP per capita levels cannot be rejected for Turkey and South Korea.

At the last stage, after the confirmation of cointegration between high-technology exports and GDP per capita, the long-run and short-run regressions are estimated. The results are given in Table 5.

Long-Run Regressions:				**Short-Run Regressions:**			
South Korea *Dependent variable: lyk*		**Turkey** *Dependent variable: lytr*		**South Korea** *Dependent variable: Δlyk*		**Turkey** *Dependent variable: Δlytr*	
lht_t	0.25*** (6.96)	lht_t	-0.051** (-2.49)	Δlht_t	0.20*** (2.89)	Δlht_t	-0.002 (-0.07)
$Trend_t$	0.04*** (42.07)	$Trend_t$	0.03*** (21.95)	Δlht_{t-1}	-0.02 (-0.27)	Δlht_{t-1}	0.09*** (3.06)
$D1998_t$	-0.07** (-2.36)	$D2001_t$	-0.079** (-2.20)	Δlht_{t-2}	0.17** (2.63)	Δlht_{t-2}	-0.08*** (-3.44)
c	8.35*** (75.50)	$D2008_t$	-0.06* (-2.01)	Δly_{t-1}	0.04 (0.20)	Δly_{t-1}	0.25** (2.07)
		$D1998_t$	0.07* (1.92)	ecm_{t-1}	-0.6139** (-2.55)	Δly_{t-2}	-0.08 (-0.34)
		c	8.46*** (440.82)	c	0.04*** (3.92)	ecm_{t-1}	-0.9945** (-3.43)
						c	0.02* (1.90)
R^2:0.9915,Adj.R^2: 0.9908, F:13.51[0.000], DW: 0.985, BG (2): 0.75(0.49), BPG(4): 0.34 (0.85)		R^2: 0.9587,Ad.R^2: 0.9465, F: 78.90 [0.000],DW:1.66, BG (2): 0.47(0.63), BPG(5): 0.49(0.78)		R^2: 0.5583, Adj. R^2: 0.4285, F: 4.30 [0.01], DW: 1.93, BG (2): 0.49(0.61) BPG(5): 2.34(0.09)		R^2: 0.6201, Adj. R^2: 0.4777, F: 4.35 [0.008], DW: 2.18, BG (2): 0.89(0.43) BPG(6): 1.72(0.18)	

Table 5. *Estimated Long-Run and Short-Run Regressions for South Korea and Turkey*

*Notes. *, **, *** denote significance at α=0.10, 0.05 and 0.01 significance levels. For the parameter estimates, the t-values are given in parentheses. In the diagnostics tests given at the bottom of the Table, BPG is the Breusch-Pagan-Godfrey test of heteroscedasticity; BG is the Breusch-Godfrey LM test of autocorrelation. In both tests, the F test statistic is reported and the degrees of freedom is given in parentheses.*

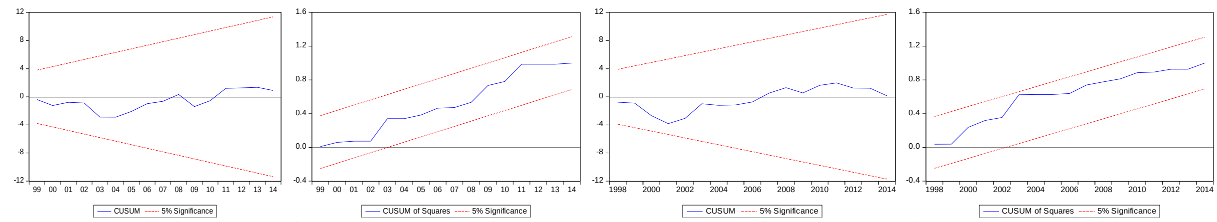
The long run models are estimated with dummy variables corresponding to 1998 (donated as D1998), the post effects of 1997 Asian Crisis in South Korea. Further, following the ZA and LS tests, a dummy variable is also added for the year 2008 (denoted as D2008) which corresponds to the Global Economic Crisis, however, the parameter of D2008 could not be accepted as statistically significant at 5% significance level. The long-run regression is estimated with D1998 dummy variable and the trend variable following the previous analyses. According to the results, the positive impact of high tech exports on GDP per capita cannot be rejected at 1%

significance level and a 1 % point increase in *lht* results in a 0.25%-point increase in GDP per capita levels in South Korea. Further, as noted in the unit root tests, a trend variable entered significantly to the model. The parameter of the 1998 Crisis is statistically significant and points at the negative effect of the crisis on the GDP per capita of South Korea.

The short-run regression results for South Korea are reported at the second part of the Table 5. The parameter of the error correction term (*ecm*) is negative and between 0 and 1 in absolute terms. The *ecm* parameter is statistically significant and is estimated as -0.61 suggesting that 61% of the deviations from the long-run equilibrium is corrected in 1 period (i.e. 1 year) in the short run for South Korea and the duration of the error correction takes 1/0.61=1.64 period. Further, though the SIC information criterion suggested inclusion of the 1st lag only, following Akaike AIC criterion, the second lag of $\Delta lht_{t\ is}$ is also added to the short-run model to overcome the autocorrelation in residuals. The parameter of Δlht_t and Δlht_{t-2} are estimated as 0.20 and 0.17, both positive and statistically significant. The parameter estimates of high-tech exports' growth rates also suggest positive impacts of high-tech exports on economic growth.

The results of the cointegration analysis for Turkey are reported 2nd and 4th columns of Table 5. The long run model for Turkey is estimated with dummy variables corresponding to 1998, post effects of the 1997 Asian Crisis, the 2001 Crisis and the 2008 Global Recession. According to the results, parameters of D2008 and D1998 are statistically significant at 10%, the parameter of D2001 is statistically significant at 5% significance level. One striking result in the long-run regression is that, the parameter of high tech exports unexpectedly negative (-0.05) and is statistically significant at 5% significance level. As a result, the positive effects of high tech exports on GDP per capita levels cannot be accepted for Turkey. If the short-run regression results is evaluated, the parameters of Δlht_{t-1} and Δlht_{t-2} are statistically significant and the relevant parameter estimates are calculated as 0.09 and -0.08; suggesting that, in accumulated terms, the effect of high tech exports growth rates almost cancels out suggesting a very limited positive effect of high-tech export growth on economic growth rates.

The parameter of the *ecm* term is calculated as -0.9945 suggesting that 99.45%, i.e. almost all, of the deviations from the long-run equilibrium are corrected within 1 year. According to the diagnostic tests, the Breusch-Godfrey autocorrelation and Breusch-Pagan-Godrey heteroscedasticity tests suggest rejection of autocorrelation and heteroscedasticity in the residuals. Additionally, CUSUM and CUSUMSQ tests suggest that parameter stability cannot be rejected for the models estimated (See Figure 7).



a.CUSUM test,Turkey b.CUSUM-SQ test,Turkey c.CUSUM test,South Korea d.CUSUM-SQ test,South Korea

Figure 7. *CUSUM and CUSUM-SQ Tests for Parameter Instability*

The overall results suggest that, while the increases in high technology manufactured export goods contributed positively on the GDP per capita levels of South Korea, this conclusion cannot be derived for Turkey. According to the results, such positive effects exist only in the short-run with a very limited amount. Furthermore, given the fact that the percentage of exports in GDP in Turkey compared to South Korea, the percentage of high technology exports in manufactured goods exports is even a lower percentage, as noted in Figure 5. As a result, even though a very little positive impact of high technology exports' growth rates on economic growth rates could be observed in the short-run regression of Turkey, this positive effect cannot be accepted to result in increases in the GDP per capita growth rates considering the percentage of high-technology exports in total exports in Turkey. This conclusion could be easily drawn by comparing the magnitude of the parameter estimates obtained for South Korea to those of Turkey. However, this conclusion shouldn't be considered discouraging since Turkey could benefit in the future by investing in R&D that is also directed towards the development of high technology and comparatively advantageous products within a dynamic comparative advantage approach.

6 Conclusions

In 1950's both Turkey and South Korea were two agrarian countries having capital shortage and enterprises. Market institutions for commerce, trade and finance were insufficient. The government had to take the lead to mobilize internal resources, to administer foreign aids, and to direct the allocation of resources to develop industrialization. Korea's powerful government agencies insulated from political or legislative interference were in charge of industry planning and development. Korean government's successful use of selective intervention is designed to promote and develop the domestic industries in the strategic, high-technology sectors. In general, the policy of both countries succeeded in sustaining a considerable rate of export-led growth. But, South Korea's growth was spectacular in comparison to Turkish case. Their growth rate, which was quite similar in 1960's has considerably diverged beginning with 1980's. Korea was particularly successful about industrial upgrading of its export commodities that is, in changing its leading exports from low tech, labor intensive light industrial goods, to heavy industrial goods, then high-tech products because it has developed a comparative advantage in R&D activity and new product introductions. Additionally, the high-technology exports were also considered as a variable that was also under the influence of R&D in the country. The large and positive impact of R&D on high technology exports had been investigated and been shown in the empirical research as discussed in the literature review section.

In the empirical section, the high technology exports and GDP per capita variables were evaluated for stationarity, structural breaks and cointegration for South Korea and Turkey. At the first stage, the variables are tested for structural unit roots with ZA and LS tests in addition to traditional ADF, PP and KPSS unit root and stationarity tests. The test results suggested that in addition to obtaining the conclusion that both the GDP per capita and high technology exports variables as following I(1) processes, an initial information was also attained in terms of determining the structural break dates. The estimated structural breaks coincided with the post effects of 1997 Asian Crisis and the 2008 Global Recession for South Korea. For Turkey, 2001 Economic Crisis were also determined to be added to the cointegration tests as exogenous deterministic factors in addition to 1997 and 2008 Economic Crises.

At the second stage, the cointegration between the variables were analyzed with Engle-Granger and Johansen cointegration tests with the incorporation of the estimated structural breaks as dummy variables entering the testing procedure as exogenous deterministic factors. According to the test results, for both Turkey and South Korea, the long-run relationship between high-technology exports and GDP per capita levels could not be rejected. At the third stage, the long run and short run regression models with error correction mechanisms were estimated. For South Korea, the parameter estimates suggested that in both of the long-run and short-run models, high technology exports had strong positive impacts on GDP per capita and economic growth rates. However, the results obtained for Turkey suggested a different result: such a positive effect of high-technology exports could not be drawn for the analyzed period. Additionally, though a very limited positive effect of high-technology exports' growth could be observed only for the short-run regression of Turkey, this effect is very limited and point at a strong difference from the results obtained for South Korea.

Given the fact that the slightly low percentage of high-technology manufactured exports in total exports of Turkey, the conclusion that Turkey benefited from high-technology exports could not be derived from the empirical results. However, the results obtained at this point should encourage the future trade and development policies of Turkey. Nevertheless, Turkey could benefit in the future by investing in human capital and R&D which are also directed towards the development of high technology and comparatively advantageous products to alter the comparative advantages in favor of the country.

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