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The Effects of Technological Development and High-Tech Industrial Production on Export in Turkey

Türkiye'de Teknolojik Gelişme ve Yüksek Teknolojili İmalat Sanayi Üretiminin İhracat Üzerindeki Etkileri

Ayberk Şeker[1]

Abstract

The level of competition among the countries in the international markets has increased with the globalization process. The countries increase the added value of the products they export and achieve international competitive advantage along with their technological developments and high-tech industrial production. This study investigates the effects of technological developments and high-tech industrial production on export value of Turkey. In this regard, Zivot and Andrews unit root test with structural break, ARDL bounds test, Granger and frequency domain causality test has applied on variables. In the scope of this study, monthly data of patent applications, patent grants, high-tech industrial production index and export value index between 2010 and 2020 were used. As a result of the study, it is found that technological accumulation and high-tech industrial production index increase the export value index in Turkey. On the other hand, it is seen that there is bidirectional causality relationship between technological accumulaiton and high-tech industrial production. In addition, it is determined that there is unidirecitonal causality relationship from technological development and accumulation to export value index.

Keywords: *Export Value Index, Technological Development, High-Tech Industrial Production, ARDL Bound Test, VAR Granger Causality Test, Frequency Domain Causality Test.*

Öz

Küreselleşme süreci ile beraber, uluslararası piyasalarda rekabet düzeyi artmıştır. Ülkeler sahip oldukları teknolojik gelişme düzeyleri ve yüksek teknolojili sanayi üretimleri ile birlikte, ihraç ettikleri ürünlerin değerini arttırmakta ve uluslararası rekabet üstünlüğü elde edebilmektedirler. Bu çalışma ile Türkiye'nin sahip olduğu teknolojik gelişme düzeyi ve yüksek teknolojili sanayi üretiminin ihracat değeri üzerindeki etkisi araştırılmaktadır. Bu bağlamda değişkenlere Zivot ve Andrews yapısal kırılmalı birim kök testi, ARDL sınır testi, Granger ve frekans alanı nedensellik testi uygulanmıştır. Çalışma kapsamında; teknolojik gelişme, yüksek teknolojili sanayi üretimi ve ihracat değerini temsilen; sırasıyla patent başvuru sayıları ile kabul edilen patent sayıları, yüksek teknolojili sanayi üretim endeksi ve ihracat değer endeksine ait 2010-2020 dönemini kapsayan aylık veriler kullanılmıştır. Çalışma sonucunda, teknolojik birikimin ve yüksek teknolojili sanayi üretiminin Türkiye'nin ihracat değer endeksini yükselttiği tespit edilmiştir. Bununla birlikte, teknolojik birikim ve yüksek teknolojili sanayi üretimi arasında iki yönlü, teknolojik gelişmelerden ve birikimden ihracat değer endeksine doğru ise tek yönlü bir nedensellik ilişkisi olduğu tespit edilmiştir.

Anahtar Kelimeler: *İhracat Değer Endeksi, Teknolojik Gelişme, Yüksek Teknolojili Sanayi Üretimi, ARDL Sınır Testi, VAR Granger Nedensellik Testi, Frekans Alanı Nedensellik Testi.*

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Introduction

Nowadays, the level of competition among the countries in the international markets has increased with the globalization process. The most important factor affecting the international competition is the level of technological development of the countries (Tekin and Hancıoğlu, 2018: 898). In addition to this, the importance of technological development and the production of high-tech products has increased in the economic growth and international trade of countries (Çütçü, 2017: 586).

Schumpeter (1934) argues that technology is an important factor determining competitiveness and innovation is the evolution of physical factors (capital and labor) (Reigado, 1997: 140). Development of new products or transformation of existing products into new products, constitution of new production methods based on scientific developments and development of new organizational paths by any industrial sector are described as an innovation, according to Schumpeter (Giacchero etc., 2006: 175; Reigado, 1997: 141). Therefore, innovation has become an important determinant of value added in the exports of countries. According to Schumpeter (1934), technological innovation is an important technological development in terms of product and process, which occurs as a new generation or occurs in existing products and processes (Galende, 2006: 301). In this respect, the importance of measuring technological development and innovation processes has increased. Accordingly, research and development expenditures, research and development personnel numbers and patent numbers are considered as the most important indicators of technological development and innovation in the literature (Basberg, 1987; Jonason, 1982; Scherer, 1965; Nelson, 1981; Roberts, 1974; Eaton ve Kortum, 1996; Freire-Serén, 1999; Sungur etc., 2016).

In globalized international markets, the technological know-how and technological development capacity of the countries have significant advantages in international competition and international trade (Di Pietro and Anoruo, 2006: 134). Technological development and high technology production have become the most important factor for countries in achievements of international trade. Countries can be superior to each other in accordance with their technological capacities (Şahbaz etc., 2014: 48).

The major problem focused on in the studies on technological development has been measuring technological development. Indicators such as research and development expenditures, research and development personnel numbers and patent applications are used in order to reveal technological development (Schmookler, 1966; Basberg, 1987; Chakrabarti, 1989: 100; Smith, 1992: 383; Amable and Verspagen, 1995; Jacobsson et al., 1996; Young, 2002; Bozkurt, 2008; Dubaric et al., 2011; Chaturvedi and Srinivas, 2012). The number of patent applications representing the technological development and the number of patent grants as representing technological accumulation are used within the scope of this study.

The patent applications and grants of the countries show the number of inventions that are realized within the country and express how effective the research and development system works. The patent applications and grants demonstrate the research and development capacities of the countries and measure the output based on the research and development. At the same time, the patent applications and grants of countries reflect the innovation potential of countries (Ang et al., 2015: 275).

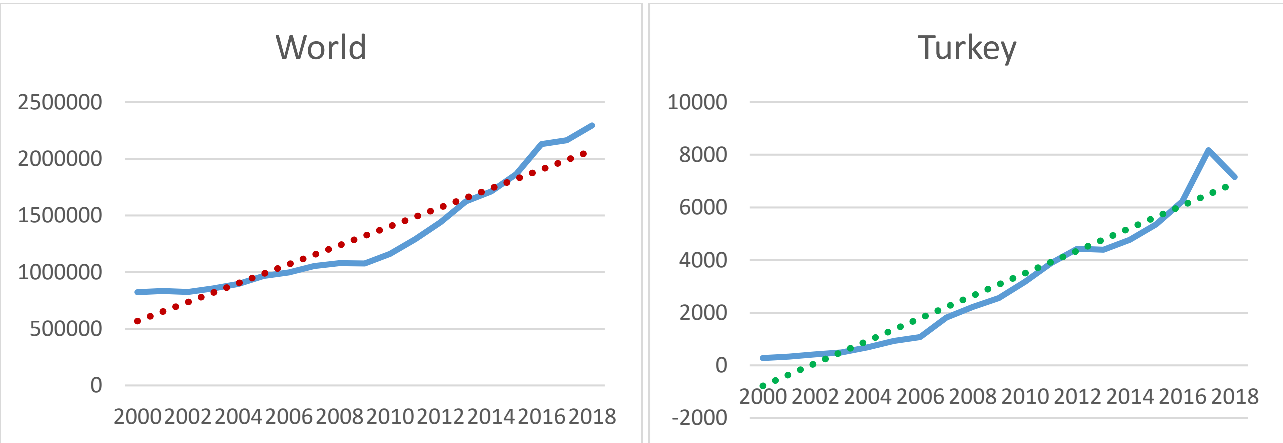

Figure 1. Patent Applications, Residents (2000-2018)

Source: World Bank Database, 2020.

According to Acs et al. (2002), research and development expenditures are considered as inputs of innovation process, while the patent applications and grants resulting from innovation studies are accepted as outputs. In addition, Griliches (1998) states that the patent applications and grants are substantial indicators of innovation activities. Despite some disadvantages, patent statistics are seen as the most important source of analyzing technological progress.

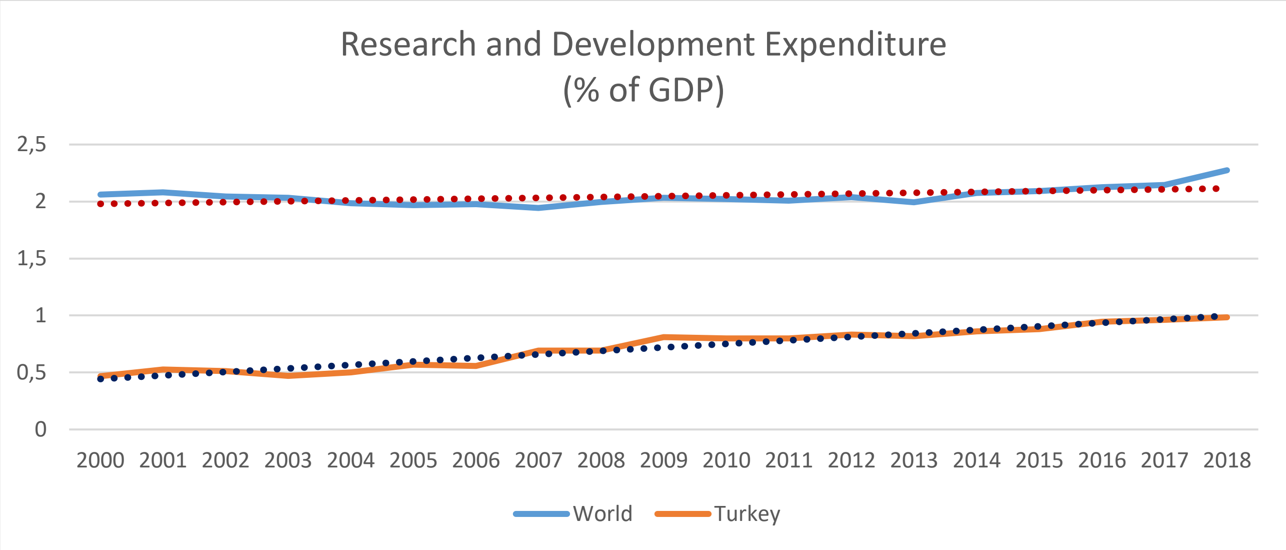

Figure 2. Share of Research and Development Expenditure in GDP (2000-2018)

Source: World Bank Database, 2020.

Figure 1 and 2 show the resident patent applications and share of research and development expenditure in GDP in Turkey and World between 2000 and 2008. According to the Figure 1, it is seen that resident patent applications have been increasing over the years in a similar global trend. In addition, it is observed that the R&D expenditures in Turkey have been rising at a higher level than the global research and development expenditure trends. In this regard, it is seen that there is a need to increase the share of research and development expenditure in Turkey and support innovative initiatives in order to ensure increment of technological developments and export values.

Today, developing countries have begun to realize the importance of technological developments in order to exist in international competition. In this respect, they have started to realize various research and development investments for technology development and try to gain a place in global competition by exporting their technological products (Çetin, 2016: 32). The added value of the products which are exported has begun to rise conjunction with the developing technological level. In this direction, as the level of technological accumulation and technological development of the countries increase, an increase on the value of the products, which they export, is expected. The export value index shows the change in the total export value. The increase of technological levels of countries and the increment of production of high technology products are also expected to increase the export value index.

Know-how which is obtained through technological developments both increases the efficiency of the production processes of the countries and ensures the production of high technological products (Yıldırım and Kesikoğlu, 2012: 167). Accordingly, as the production of high-tech products increases, the gains from exports are expected to increase due to the increment in productivity. As a result, the export value index is also expected to increase as the production of high technology increases.

Falvey (1981) and Falvey and Kierzkowski (1987) explain that capital-rich countries have a high rate of exporting high-quality products because high-quality products can be produced in countries with capital intensive technology based on Heckscher-Ohlin. However, Flam and Helpman (1987) argue that quality differences are caused by technological differences rather than differences in factor endowment. Accordingly, it is suggested that the quality differences between the products of the countries depend on the technological knowledge they have.

Studies about the effects of technological development and knowledge and high-tech production on the export value are substantial for the literature. This study aims to reveal the impacts of technological developments and high-tech production of Turkey on export value. The effects on the quality of export products by focusing on the link between the technological capacity and value-added exports of Turkey will be analyzed in order to contribute the literature. In terms of trade and production policies, studies reveal the impact of technological development and knowledge on export value are significant. Accordingly, there is literature review on studies analyzing the effects of high technology production and technological development on export value in the first part of the study. Then, there is the data and methodology part where the effects of high-tech industrial production, technological development and capacity on the export value index are analyzed. Finally, the findings are evaluated and policy recommendations are made in the conclusion part.

1. Literature Review

Studies examining the effects of high-tech industrial production and technological development on the export value of the countries have great importance since they lead policymakers in terms of directing R&D investments. Conjunction with the understanding that technology is an important factor in the development of new products and production processes, many researches in the literature have started to focus on technological development.

Lall (1993) is stated that there are five important issues for countries to make technological progress. These are R&D incentives for companies, skilled human capital, technical information and support, investment support and technology policies of governments. The complex interaction of these factors determines the willingness and ability of firms to develop their technological capabilities. According to Lall (1993), the promotion of capacity building is a vital part of the industrial development strategy. It also shows that active state involvement is necessary to ensure technological development in the presence of market failures. The export of high quality and differentiated products is related to the activities of technological development. However, it is stated that countries should be encouraged research and development activities and technological development if countries aim to increase the quality of the products, which they export (Faruq, 2010; Alvarez and Fuentes, 2011; Bayar and Tokpunar, 2014).

Technological developments have great importance for economies based on technology and knowledge in nowadays. Technology, which is crucial in terms of increasing the economic growth and international trade volumes of countries, is also considered risky due to the possibility of unsuccessful results despite intensive technology investments. However, research and development (R&D) and technological developments are substantial in sense of accelerating the economic growth and increasing their international trade of countries through new products and new production processes (Olteanu, 2010: 1; Ćorović et al., 2019: 311; Şeker, 2020: 54). Accordingly, Flam and Helpman (1987) indicates an increase in export volumes and value added exports of countries producing value added products. Martinez-Zarzoso and Burguet (2000) have stated that the differences between the export values among the countries can be explained by the quality differences of the products. In this respect, it is revealed that the increments of the export values and the incomes from the exports will rise with the increment of the technological development of the countries. Lou and Yan (2018) have highlighted that R&D expenditures and high-tech production increase export value added by using principal component analysis in their studies. At the same time, they have also stated the importance of technological progress to improve countries' position in the global value chain and increase export values (Shieh and Pei, 2013: 601-602; Konak, 2018: 58).

It is stated that the export prices of developed countries are higher than the other countries and this situation is originated by the quality and product differences in exports of developed countries in the literature. Therefore, it is propounded that the export prices and the profit opportunities from export will increase as a result of technological developments in production (Hummels and Klenow, 2005). Furthermore, Batista (2011) has remarked that there is an increase in the wealth of export countries as a result of the increase in the unit values of the products exported.

It is stated that countries require to classify the technology in their exports and production in order to increase their export values and innovate their production processes. Although there are many ways to classify products by technology, it is common to distinguish between resource-based, labor-intensive, scale-intensive, differentiated and science-based producers. Thus, the level of technology in exports and products can be classified as resource-based manufactures, high technology manufactures, medium technology manufactures and low technology manufactures (Lall, 2000: 340-341). In addition, Wang et al. (2020) have argued that high-tech industrial production increased export added value. Moreover, they have stated that the main reason for the increase in China's export value added is the increment in export scale and industrial cooperation with other economies (Wang et al., 2020). Furthermore, Akcan (2019), who investigates the relationship between the export value index, production and investments, has revealed that there is a bidirectional causality relationship among the production, investments and the export value index.

When the studies carried out in the literature are evaluated, there are studies that there is a positive effect of their technological development and high-technology productions on the export value of countries, but there are few studies that are directly evaluating the relationship between export value index and technological development. In terms of originality in the literature, this study will try to determine the effects of high technology production within the manufacturing industry and technological developments on export value.

2. Data and Methodology

Cointregration and causality relationships among export value index, patent application, patent grants and high-tech industrial production index are evaluated in this study. Before analyzing cointregration and causality relationships, correlation relationship is analysed among the variables. Afterwards, series of export value index, patent application, patent grants and high-tech industrial production index are examined by means of Zivot-Andrews unit root test with structural break in order to analyze stationarity among the series. Then, the cointegration relationship between variables is examined by means of ARDL bounds test. After the cointegration test, Granger and Breitung and Candelon causality tests are applied in order to test the causal relationship among export value index, patent application, patent grants and high-tech industrial production index. Long-term relationships were tested with the ARDL bounds test because they are stationary at the levels of the variables in the model. In addition, Breitung and Candelon causality test is used to analyze the causality relationships between variables at different frequencies, namely in the short, medium and long term.

Correlation analysis informs us whether a relationship among the variables exists, however information about causal relationship or direction of the relationship between the variables can not be obtained (Gujarati, 2004: 696). Elasticity relation among the variables shows effects of patent application, patent grants and high-tech industrial production index on export value index. After the structural break unit root test of variables, ARDL bounds test can be carried out.

Data set of patent applications and patent grants gained from Turkish Patent and Trademark Office. High-tech industrial production index was obtained from the Central Bank of the Republic of Turkey. Also, data of export value index obtained from the Turkish Statistical Institute. The base year of both high-tech industrial production index and export value index is 2010. It is used monthly data between 2010 and 2020 in the model. EVI, PAPP, PGRA and HIPI represent export value index, patent application, patent grants and high-tech industrial production index, respectively. Turkish Patent and Trademark Office has announced monthly data of patent applications and patent grants since 2010. Therefore, the data has started from 2010. At the same time, it is used data for the 2010-2020 period in order to eliminate the negative effects of the 2001 economic crisis of Turkey and the 2008 global economic crisis on the analysis. The analyzes were carried out through EViews10 and Stata15 programs.

The functional relationship among export value index, patent application, patent grants and high-tech industrial production index can be represented as follows (1,2);

$$ln(EVI)_t = \beta_0 + \beta_1 ln(PAPP)_t + \beta_2 ln(HIPI)_t + \varepsilon_t \quad (1)$$

$$ln(EVI)_t = \beta_0 + \beta_1 ln(PGRA)_t + \beta_2 ln(HIPI)_t + \varepsilon_t \quad (2)$$

where $ln(EVI)_t$, $ln(PAPP)_t$, $ln(PGRA)_t$ and $ln(HIPI)_t$ are the logarithmic forms of export value index, patent application, patent grants and high-tech industrial production index, respectively. Logarithmic forms of the variables are used in order to reduce skewness and variances among the variables. In addition, logarithmic forms of the variables reduce the range of the variables. This ensures that the outlier values do not overly affect the estimators. Moreover, logarithms of the data ensure to reveal percentaged relationship among the ratios.

First model shows the effects of high-tech industrial production index and patent application as technological progress on export value index, whereas the second model demonstrates the impact of high-tech industrial production index and patent grants as technological accumulation on export value index. The research models are derived from the literature by evaluating the studies that analyze the export value index (Martinez-Zarzoso and Burguet, 2000). $ln(HIPI)_t$ variable is used to evaluate the effects on Turkey's export value of high-tech industrial production on behalf of gross domestic product in the model because of absence of monthly data for gross domestic product. $ln(PAPP)_t$ and $ln(PGRA)_t$ are variables is employed in the model in order to assess their impact of Turkey's technological development and technological accumulation on the export value index.

2.1. Unit Root Analysis

The variables must be stationary in their levels or first differences in order to test the relationships between the variables within the scope of the analysis. Stationarity of series is examined by Augmented Dickey Fuller (ADF) unit root test (Dickey & Fuller, 1979-1981) and Phillips-Perron (PP) unit root test (Phillips & Perron, 1988) and Zivot & Andrews (Z&A) unit root test with structural break (1992). The null hypothesis of the Augmented Dickey Fuller and Phillips-Perron unit root tests are that "time series are not stationary (there is at least one unit root)". Augmented Dickey-fuller (ADF) (3) test and Phillips-Perron (PP) (4) test, respectively, is based on the model shown below;

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \cdots + \varepsilon_t \quad (3)$$

$$\Delta y_t = \alpha y_{t-1} + x_t' \delta + \varepsilon_t \quad (4)$$

One of the main reasons why variables include unit roots in time series analyzes is structural breaks in economic processes. Structural breaks that occur in economic processes can affect trends, averages, or both trends and averages of the series in the analysis, and thus cause spurious unit root. In other words, results can be obtained in accordance with the fact that series appear stationary, although they contain unit root or they are stationary despite giving unit root results in traditional unit root analyzes that do not take structural breaks into account. It is foreseen that the outputs obtained may be deviaent and inaccurate, if the tests that do not consider the structural breaks and economic shocks occurring in the series in the analysis are carried out. In this respect, Zivot & Andrews (1992) unit root test with a structural break were performed, because of the high likelihood of a structural break in Turkey's economy. Zivot & Andrews unit root test (1992) examining the stability under one structural break, is applied in this study, to check the series by structural breaks that occurred in Turkey. Three models of Zivot & Andrews unit root test are applied. Model A (5) states a break only in the intercept, Model B (6) states a break only in the trend and Model C (7) stands for a break both in intercept and trend according to Zivot & Andrews. The three models are shown as follows;

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \theta DU_t + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t \tag{5}$$

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \gamma DT_t + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t \tag{6}$$

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \theta DU_t + \gamma DT_t + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t \tag{7}$$

2.2. ARDL Bound Test

After determining the order of stationarity as a result of the unit root tests of the series, cointegration tests are performed to investigate the long-term relationships between variables. The ARDL boundary test analyzes the cointegration relationships between variables that are stationary at the level and allows the estimation of short and long-term coefficients (Pesaran et al., 1999; Pesaran et al., 2001). In other words, the main reason for using the ARDL bounds test is that it allows the analysis of long-term relationships regardless of the integration degree of variables. In addition, the long and short run coefficients can be estimated synchronously through the ARDL bounds test. ARDL bounds test which is based on an autoregressive distributed lag model is given below (8);

$$\Delta y_t = c_0 + c_1 t + \pi_{yy} y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{r=1}^{p-1} \psi_i' \Delta z_{t-i} + \omega' \Delta x_t + \theta w_t + u_t \tag{8}$$

In the model, c_0, t, w_t, u_t, πyy and $\pi yx.x$ represents the autonomous parameter, trend, the independent variables vector, the non-autocorrelated error term and long-term factors, respectively. As a result of the ARDL bounds test, three cases can be obtained. The first case is that there is a cointegration relationship in case of the test statistic are higher than the upper critical value. The second case is that there is doubt about the cointegration relationship in case of the test statistic is between the lower and upper critical value. The third case is that there is no cointegration relationship in case of the test statistic is below the lower critical value.

2.3. Causality Analysis

In case of there is a relationship between the variables in cointegration model, it is expected that there will be a causal relationship between the series. A causality analysis that was revealed by Granger (1986) and Engle-Granger (1987) is carried out in order to reveal the direction of causality among the variables. If the calculated F-statistic in the analysis rejects the null hypothesis, the coefficients of the variables in the equation are statistically significant. In this situation, Granger causality from variable X to variable Y will be reached (Granger, 1969). The model is shown as follows (9);

$$\mathrm{Y} = \alpha + \sum_{i=1}^{k} \beta_i Y_{t-i} + \sum_{i=1}^{k} \delta_i X_{t-i} + \varepsilon_t \tag{9}$$

In addition to the Granger causality analysis, frequency domain causality test is used in order to reveal the causality relationships between variables for different periods within the scope of the study. Frequency domain causality test is applied to reveal the causality relationships of the variables in the short, medium and long term. This causality approach was developed by Granger (1969, 1980), Geweke (1982), Hosoya (1991), Breitung and Candelon (2006).

$$x_t = c_1 + \sum_{j=1}^{p} \alpha_j x_{t-j} + \sum_{j=1}^{p} \beta_j y_{t-j} + \sum_{k=p+1}^{p+d_{max}} \alpha_k x_{t-k} + \sum_{k=p+1}^{p+d_{max}} \beta_k y_{t-k} + \varepsilon_t \tag{10}$$

While traditional causality tests perform analyzes with a single causality statistic, the frequency domain causality test allows the causality relationships of various frequencies to be examined (Ciner, 2011). Thus, it is investigated the existence of a temporary or permanent causality relationship at different frequencies between variables.

2.4. Empirical Findings

Before examining the relationship among export value index, high-tech industrial production index, patent application and patent grants for Turkey, descriptive statistics of the data set are tested, and the findings are presented in Table 1. According to the descriptive statistics, average monthly value of export value index, high-tech industrial production index, patent applications and patent grants were 131.531, 100.045, 421.762 and 124.177 respectively in Turkey between 2010 and 2018. Patent applications have higher volatility than other variables, but the standard deviation values of all variables are high. The height of volatility can be seen from the maximum and minimum values.

Table 1. Descriptive Statistics

	EVI	PAPP	PGRA	HIPI
Average	131.531	421.762	124.177	100.045
Maximum	173.259	1398	301	233.142
Minimum	82.546	187	25	37.729
Standart Deviation	18.143	163.071	58.471	38.703
Skewness	-0.357	2.905	0.756	0.653
Kurtosis	3.107	16.531	3.125	3.051
Jarque-Bera	2.821	1174.458	12.478	9.264
Probability	0.244	0.000	0.002	0.009
Observation	130	130	130	130

Table 2 demonstrates the correlation relationships among the variables. The correlation relationships among the variables do not involve any causal relationship. According to the correlation matrix, it is observed that there are positive correlations among export value index, high-tech industrial production index, patent application and patent grants. It is determined that there is a linear and moderate correlation between EVI as a dependent variable and PAPP, PGRA and HIPI as independent variables.

Table 2. Correlation Matrix

	EVI	PAPP	PGRA	HIPI
EVI	1	0.374	0.478	0.691
PAPP	0.374	1	0.303	0.569
PGRA	0.478	0.303	1	0.594
HIPI	0.691	0.569	0.594	1

Figure 3 shows all variables have a rising trend between 2010 and 2020 in Turkey. It is seen that patent grants within the variables have the highest rising trend in the same period.

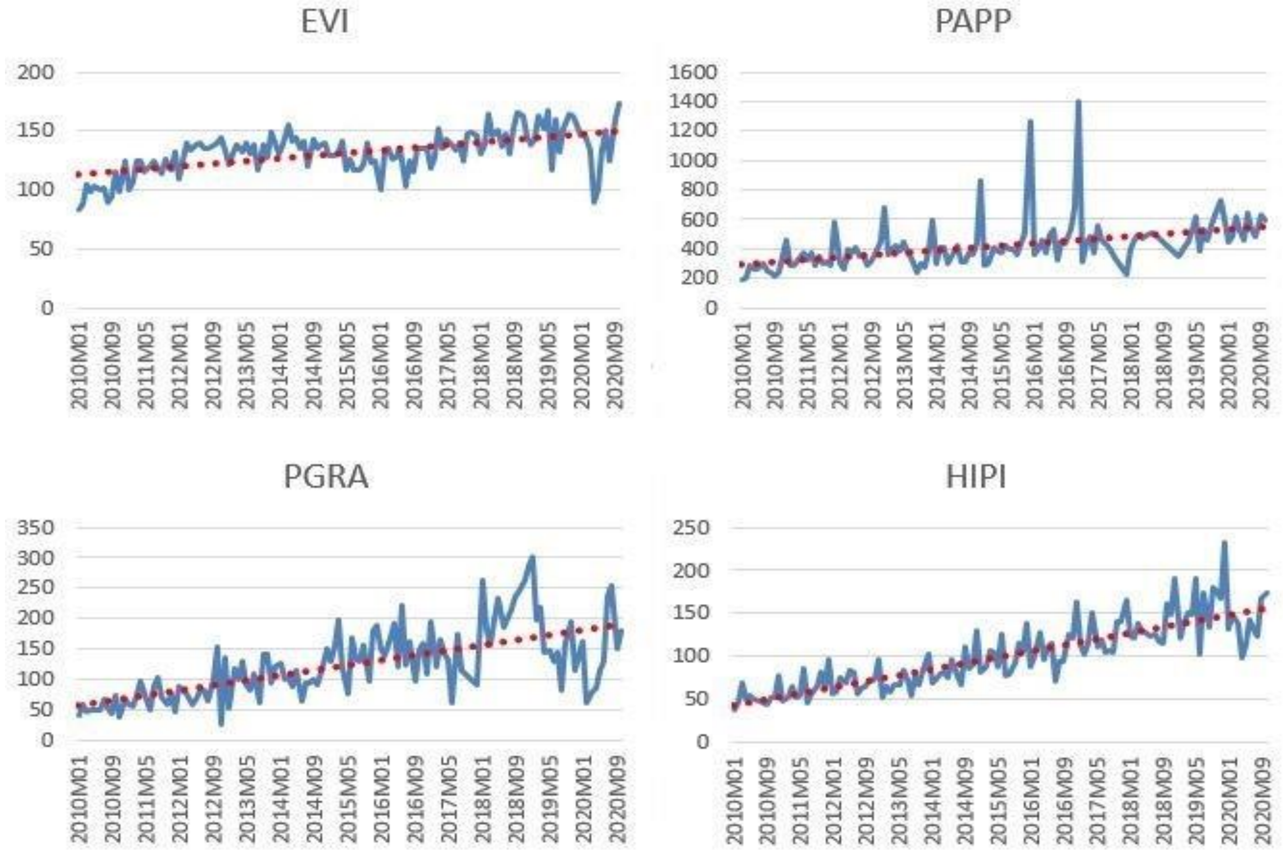

Figure 3. Slope of Variables between 2010 and 2020

After the descriptive statistics, it is required that variables are stationary whether in their levels or in their first differences in order to accept meaningful relationships between the variables. Augmented Dickey Fuller (ADF) unit root test (Dickey and Fuller, 1979-1981) and Phillips-Perron (PP) unit root test (Phillip and Perron, 1988) are used for examining stationarity of series.

Table 3. Augmented Dickey-Fuller and Phillips-Perron Unit Root Test Results

	Augmented Dickey-Fuller (Level)		Phillips-Perron (Level)	
	C	C+T	C	C+T
ln(EVI)	-5.77***	-7.04***	-5.77***	-7.26***
ln(PAPP)	-7.03***	-9.11***	-7.08***	-9.07***
ln(PGRA)	-5.82***	-8.99***	-6.48***	-9.91***
ln(HIPI)	-4.11***	-11.12***	-3.61***	-11.12***

Note: ***, denote statistically significance at the 1% level. “C” and “C+T” represent to “constant” and “constant+trend”, respectively.

Null hypothesis of Augmented Dickey Fuller and Phillips-Perron unit root test is “they are not stationary time series” (there is at least one-unit root). As can be seen in Table 3, export value index, high-tech industrial production index, patent application and patent grants are stationary at level.

Table 4. Results of Zivot and Andrews Unit Root Test with One Structural Break

	Zivot and Andrews (Level)								
	Z&A (Model A)			Z&A (Model B)			Z&A (Model C)		
	Breakpoints	**k**	**Statistics**	**Breakpoints**	**k**	**Statistics**	**Breakpoints**	**k**	**Statistics**
ln(EVI)	2011M02	0	-7.438	2012M04	0	-8.125	2012M11	0	-8.209
ln(PAPP)	2015M12	0	-8.927	2011M05	0	-9.325	2016M12	0	-11.015
ln(PGRA)	2011M02	0	-6.896	2011M03	0	-9.181	2019M03	0	-10.973
ln(HIPI)	2011M02	0	-4.709	2011M03	0	-11.096	2010M11	0	-11.209
Critical Value	Model A => %1: -4.9491 ; %5: -4.4436 ; %10: -4.1936 Model B => %1: -5.0674 ; %5: -4.5248 ; %10: -4.2611 Model C => %1: -5.7191 ; %5: -5.1757 ; %10: -4.8939								

Table 4 indicates the results of Zivot and Andrews (1992) unit root test. According to results of unit root test with one structural break, ln(EVI), ln(PAPP), ln(PGRA) and ln(HIPI) do not have unit roots with one structural break at level, meaning that these variables are stationary at their levels. The null hypothesis of a unit root with one structural break in ln(EVI), ln(PAPP), ln(PGRA) and ln(HIPI) can be rejected, meaning all variables are stationary with one structural break at their level. Zivot and Andrews (1992) unit root test results reveal that ln(EVI), ln(PAPP), ln(PGRA) and ln(HIPI) are integrated of order zero, or I(0). Due to the fact that all variables are stationary at level, analyses are continued with the ordinary least square.

There are structural breaks ln(EVI), ln(PAPP), ln(PGRA) and ln(HIPI) variables, in 2011M02, 2015M12, and 2011M02 respectively. Total export value index increased by 12 percent in 2011M02. In addition, while patent applications increased by 48 percent compared to the previous year, the number of patent applications has increased by 38 percent. Moreover, investments have been made in high technology sectors in line with the 2023 targets and the high technology production index has increased by 14 percent in February 2011 compared to the previous year.

As a result of the unit root analysis, it is determined that the variables are stationary. In other words, it is seen that the variables in the model are stationary at level. The most important point in choosing the ARDL bounds test in analysis is that it allows the variables to be stationary at level in the short and long term analysis.

Table 5. ARDL Model Selection

Research Model	Model	AIC	BIC	HQ	Adj. R-sq
Model 1	ARDL (2,3,2)	-2.106	-1.882	-2.015	0.636
	ARDL (2,3,3)	-2.097	-1.851	-1.997	0.636
	ARDL(2,2,2)	-2.094	-1.892	-2.012	0.629
	ARDL (3,3,2)	-2.091	-1.844	-1.991	0.633
Model 2	ARDL (2,2,0)	-2.095	-1.939	-2.032	0.624
	ARDL (2,2,1)	-2.091	-1.911	-2.017	0.625
	ARDL (3,2,0)	-2.089	-1.909	-2.016	0.625
	ARDL (3,2,1)	-2.082	-1.881	-2.001	0.624

The appropriate models are determined accordin to the Akaike (AIC), Schwarz (BIC), Hannan-Quinn (HQ) information criteria and adjusted R-square values in order to perform the ARDL bounds test and results are shown in Table 5. According to the results in Table 5, ARDL (2,3,2) and ARDL (2,2,0) models is found to be appropriate for Model 1 and Model 2 in line with the boundary test, respectively.

Table 6. ARDL Bounds Test Results

Research Model	Bounds Test F-Statistics	Significance	Lower Critical Value	Upper Critical Value
		10%	2.63	3.35
Model 1	5.135***	5%	3.1	3.87
Model 2	6.609***	1%	4.13	5

Note: ***, denote statistically significance at the 1% level.

ARDL limit test results are given in Table 6. According to the results, Model (1) and Model (2) are rejected at 99%, 95% and 99% significance levels and F statistics of the models are determined as 5.135 and 6.609, respectively. In this respect, it is seen that there are the cointegration relationship between In(EVI), In(PAPP), In(PGRA) and In(HIPI).

Table 7. ARDL Bounds Test Long-Term Coefficient Results

Research Model	Long-Term Coefficients		
	Variables	**Coefficients**	**T-Statistics**
Model 1	In(PAPP)	0.0305	0.238
	In(HIPI)	0.181	2.151**
	C	3.879	7.004***
Model 2	In(PGRA)	0.106	1.838*
	In(HIPI)	0.096	2.215**
	C	3.941	15.831***

Note: ***, ** and * denote statistically significance at the 1%, 5% and 10% level, respectively.

Table 7 contains long-term coefficient estimates for research models. In line with the results, it is seen that the relationship between high-tech industrial production index and export value index is positive and statistically significant in both models. In addition, it has been determined that there is a positive and statistically significant relationship between patent acceptance and export value index, while there is no statistically significant relationship between patent applications and export value index. Accordingly, %1 increase in patent grants makes an increment approximately 0.11% in export value index in the long run.

Table 8. ARDL Error Correction Model Results

Research Model	Variables	Coefficients	T-Statistics
Model 1	D(In(IDE)(-1))	-0.244	-2.891***
	D(In(YTSUE))	0.277	6.775***
	D(In(YTSUE)(-1))	0.136	2.982***
	D(In(PBAS))	0.016	0.526
	D(In(PBAS)(-1))	-0.087	-2.799***
	D(In(PBAS)(-2))	-0.051	-1.969**
	ECT(-1)	-0.365	-4.589***
	R^2= 0.59		D.W. Stat.= 2.038
Model 2	D(In(IDE)(-1))	-0.223707	-2.711***
	D(In(YTSUE))	0.284256	8.513***
	D(In(YTSUE)(-1))	0.095021	2.336**
	ECT(-1)	-0.382668	-5.205***
	R^2= 0.57		D.W. Stat.= 2.074

Note: ***, ** and * denote statistically significance at the 1%, 5% and 10% level, respectively.

Data on short-term relationships between variables are given Table 8. According to the results of the analysis, it has been determined that error correction coefficients (ECT(-1)) in the models and lagged values of export value index, patent applications and high-tech industrial production index are statistically significant. The fact that the error correction coefficients (ECT(-1)) are negative and statistically significant reveals that there is a co-integration relationship between the export value index, patent applications, patent grants and high-tech industrial production index. These results show that the deviations that occured in model reach the equilibrium again in the following periods. In other words, the effects of a shock between the export value index, patent applications, patent grants and the high-tech industrial production index is found to recover at 0.37% and 0.38% in the next period, respectively.

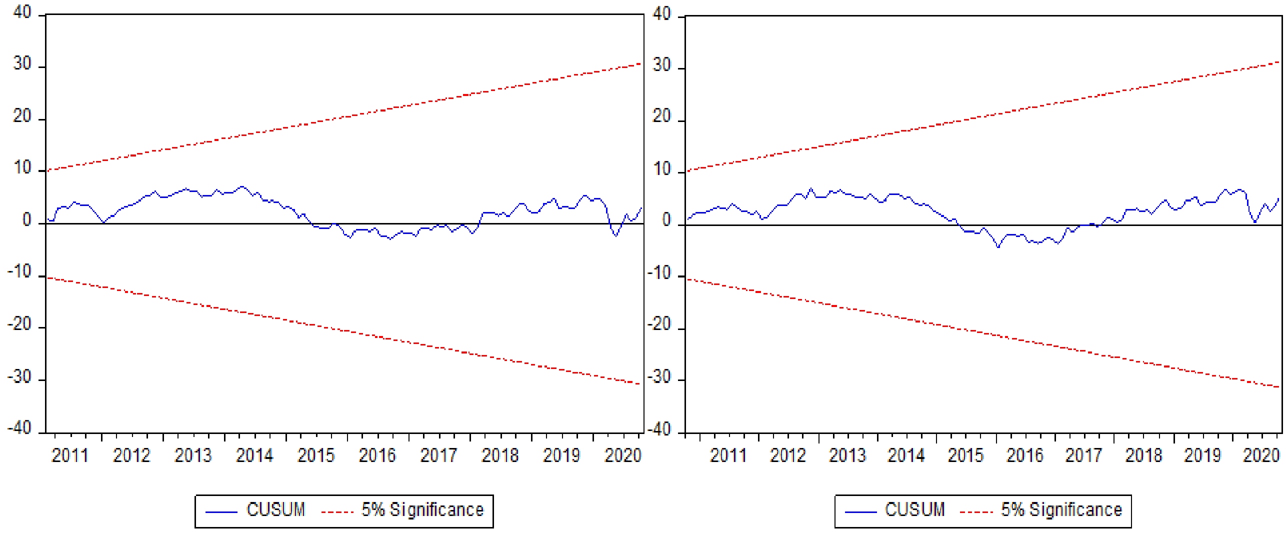

Figure 4. CUSUM Test Results of ARDL (2,3,2) and ARDL (2,2,0) Models

CUSUM tests are carried out in order to determine the stability of ARDL (2,3,2) and ARDL (2,2,0) models and to the reveal whether there is a structural change. The CUSUM test results of ARDL (2,3,2) and ARDL (2,2,0) models are shown in Figure 4. The plots of CUSUM in two models stay within the critical 5% bounds that verifies the long-run relationships between the variables and this situation demonstrates the stability of coefficients.

Table 9. Granger Causality Test Results

Hypothesis	Chi² Stat.	P. Value	Causality
ln(PAPP) does not cause ln(EVI)	15.36322	0.002***	Reject
ln(EVI) does not cause ln(PAPP)	5.074646	0.1664	Fail to reject
ln(PGRA) does not cause ln(EVI)	18.28262	0.001***	Reject
ln(EVI) does not cause ln(PGRA)	1.037825	0.904	Fail to reject
ln(HIPI) does not cause ln(EVI)	11.07152	0.136	Fail to reject
ln(EVI) does not cause ln(HIPI)	18.75914	0.009***	Reject
ln(HIPI) does not cause ln(PAPP)	22.69486	0.001***	Reject
ln(PAPP) does not cause ln(HIPI)	7.743321	0.2575	Fail to reject
ln(HIPI) does not cause ln(PGRA)	10.64748	0.005***	Reject
ln(PGRA) does not cause ln(HIPI)	18.08217	0.000***	Reject

Note: ***, ** and * denote statistically significance at the 1%, 5% and 10% level.

The results of Granger causality analysis are located in Table 9. According to the result of the Granger causality test, the causal relationships from patent applications and patent grants to export value index are significant at 1% level. Accordingly, there are causal relationships from both patent applications and patent grants to export value index. In addition, the causal relationship from patent grants to high-tech production index are significant at 1% level. Also, there is a bidirectional causal relationship between patent grants and high-tech production index, while there is a unidirectional causal relationship from high-tech production index to patent applications. Considering these results, the relationship among the variables is verified.

Three different results can be obtained as a result of the Granger causality test. These are unidirectional causality relationships and bidirectional causal relationships between the variables. The Granger causality test (1969) considers the long-term relationships between variables via the Wald and F test. Therefore, short-term causality relationships between variables are regarded. In order to resolve this situation, Geweke (1982), Hosoya (1991) and Yao and Hosoya (2000) suggested a frequency causality analysis based on spectral relationships. In addition, the frequency causality test gives the opportunity to analyze causality relationships at different frequencies between variables.

Table 10. Frequency Domain Causality Test Results

Causality Relationship	Long Term		Medium Term		Short Term	
	w=0,1	w=0,5	w=1	w=1,5	w=2	w=2,5
ln(EVI)≠>ln(PAPP)	2.977	3.145	3.785	5.041*	4.473	1.883
ln(PAPP)≠>ln(EVI)	11.144***	11.411***	12.382***	13.891***	10.226***	5.803**
ln(EVI)≠>ln(PGRA)	2.611	2.521	2.106	2.029	2.921	1.722
ln(PGRA)≠>ln(EVI)	10.801***	11.537***	14.243***	15.533***	4.139	1.643
ln(EVI)≠>ln(HIPI)	10.196***	10.457***	10.997***	7.649**	4.131	0.671
ln(HIPI)≠>ln(EVI)	2.164	2.005	1.411	1.443	5.757*	6.722**
ln(PAPP)≠>ln(HIPI)	2.999	3.596	4.182	0.579	2.261	3.189
ln(HIPI)≠>ln(PAPP)	2.947	2.579	0.611	8.693**	11.961***	1.142
ln(PGRA)≠>ln(HIPI)	3.298	4.863*	8.916**	6.928**	4.288	2.029
ln(HIPI)≠>ln(PGRA)	2.838	2.784	2.431	0.431	0.357	0.526

Note: ***, ** and * denote statistically significance at the 1%, 5% and 10% level.

Frequency domain causality results are given in Table 10 and Appendix 1. In addition to this, there is a bidirectional causality relationship between patent applications and export value index in the medium term, whereas there is a unidirectional causality relationship from patent grants to export value index in the medium and long term. Moreover, there is a unidirectional causality relationship from patent applications to export value index in the short and long term. In addition to this, there is a unidirectional causality relationship from high technology production index to export value index in the short-term, while there is a unidirectional causality relationship from export value index to high technology production index in the medium and long term. Furthermore, there is a unidirectional causality relationship from the high technology production index to patent applications in the short and medium term, whereas there is a unidirectional causality relationship from patent grants to high technology production index in the medium and long term.

Conclusion

Conjunction with the globalization process, the level of competition in international trade has increased considerably. Due to increasing level of competition, it is an obligatory situation for countries to trade products, which have value-added, and high technology. In this context, the effects of technological developments and high-technology production on export values of Turkey were investigated.

In the study, regression models examine relations between technological progress and accumulation and high technology productions and export value index of Turkey. In addition to this, causality relationships among variables are analyzed with Granger and frequency domain causality test. These methodological approaches give new perspectives to analyse relationships between technological progress and accumulation and high-technology productions and export value index of Turkey.

Firstly, regression analysis is performed in order to reveal the elasticity relations between technological developments and high-technology productions and export value index of Turkey. According to the results of the analysis, it has been confirmed that there is an elasticity relationship between these variables. According to results, 1% increment in patent grants that demonstrate the technological accumulation ensures an increase of 0.05% in the export value index. Moreover, it is seen that 1% increase in high-tech production index procures an increment of 0.002% in the export value index. These results show that technological progress has greater effects than high-tech production on export values of Turkey. Therefore, Turkey must set targets for enhancing technological progress. As technological development is achieved, the export values of Turkey will increase further and value added will be obtained. As a result of the relationship between technology and export, Turkey can implement policies that encourage research and development activities in order to increase added value in their exports.

According to the results of Granger causality analysis, there are unidirectional causality relationships from patent applications and patent grants of Turkey to the export value index of Turkey. In addition, it is determined that there are unidirectional and bidirectional causality relationships in different frequencies among the variables as results of frequency domain causality test. In this regard, increasing technological developments of Turkey will positively affect the export values of Turkey. As a result of the analysis performed in accordance with the research hypothesis, when patent applications and patent grants raise, the export value index of Turkey also follows an increasing trend. In addition to this, there is a unidirectional causality relationship from patent grants to high-technology production index, whereas there is a unidirectional causality relationship from high-technology production index to patent applications. These causality relationships show that technological progress in Turkey also increases the high-tech production. Thus, technological developments provide more added value products. According to the findings within the scope of this study, supporting the increase of technological developments of Turkey indicates that the strategy of exporting added value products will work for Turkey.

Considering the technology policies in Turkey's 2023 vision, it is aimed to increase to 40% the rate of R&D expenditures in the "high-technology". In addition to this, it is targeted to increase to 2% in R&D intensity. Within the scope of 2023 technology policies, information and communication technologies, energy and environmental technologies, nanotechnology, biotechnology and gene technologies, production process and technologies, mechatronics, material technologies, design technologies have been identified as target strategic technological industries. In accordance with these objectives, it is necessary to increase high-tech exports by increasing technological developments and raising the level of high-tech production. In this direction, Important legislative arrangements have been made such as directing savings to investments with high added value, supporting research and development activities and encouraging the regional and large-scale research and development investments. Moreover, increasing the production of import dependent intermediate goods and products and supporting investments high and medium-high technology that will provide technological transformation are emphasized as two priority targets in order to reduce the current account deficit in the investment incentive system. In addition to these, it is essential to complete the technological infrastructures required to perform the necessities of Industry 4.0 that is digital transformation revolution of our age and to make technology investments in training experts in these fields. Thus, crucial developments will be made in high technology production and export and an increase in added value in exports will be provided as a result of technology investments.

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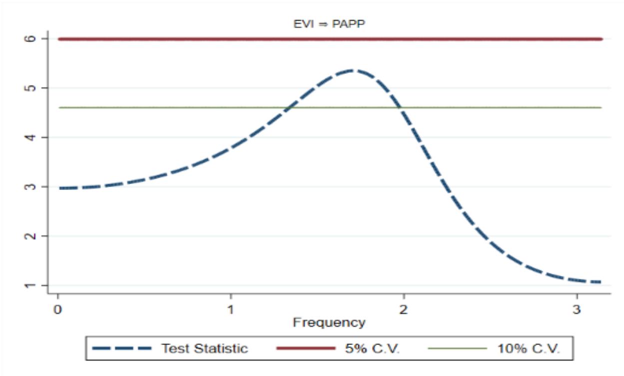
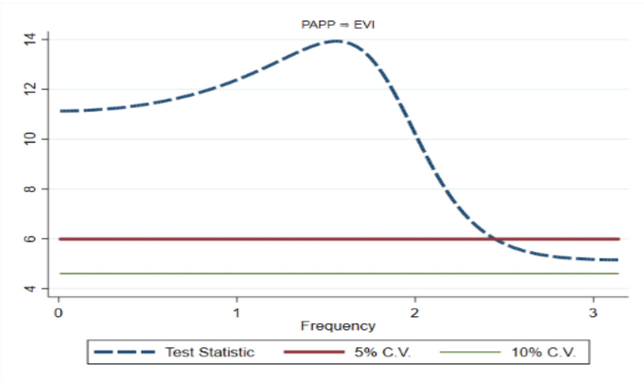
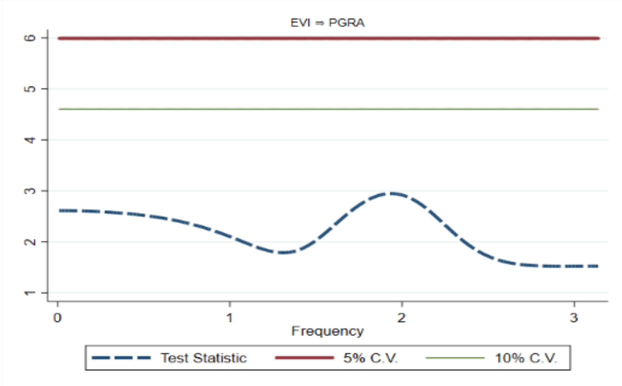
Appendix

Appendix 1: Frequency Domain Causality Relationships Between the Variables






EVI ⇒ PGRA
Frequency
Test Statistic
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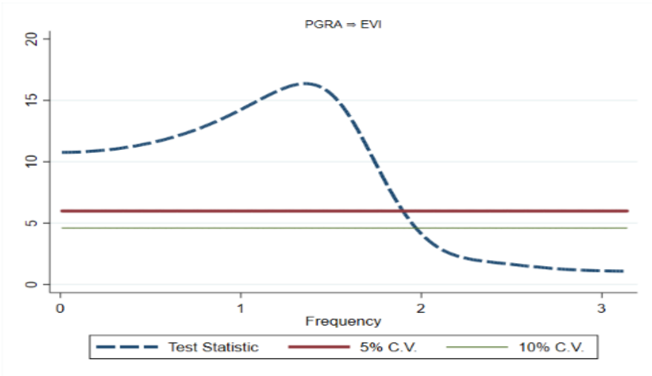
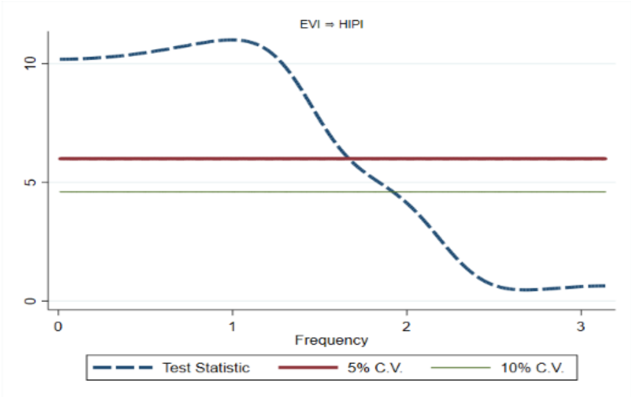
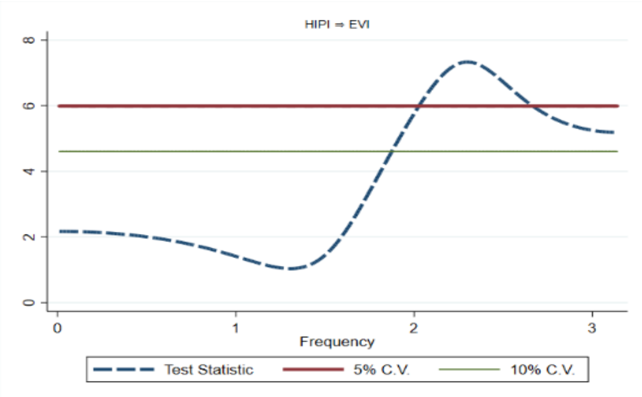
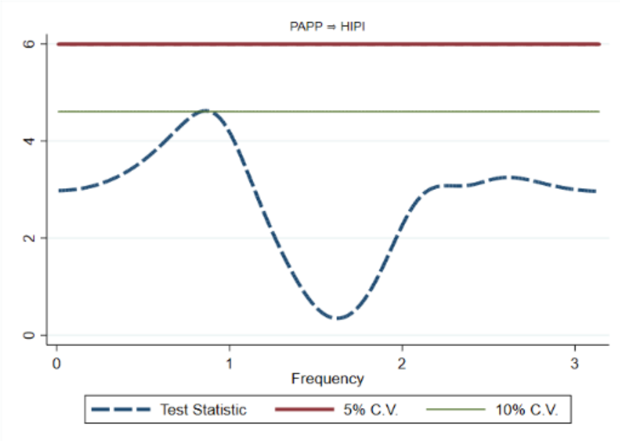
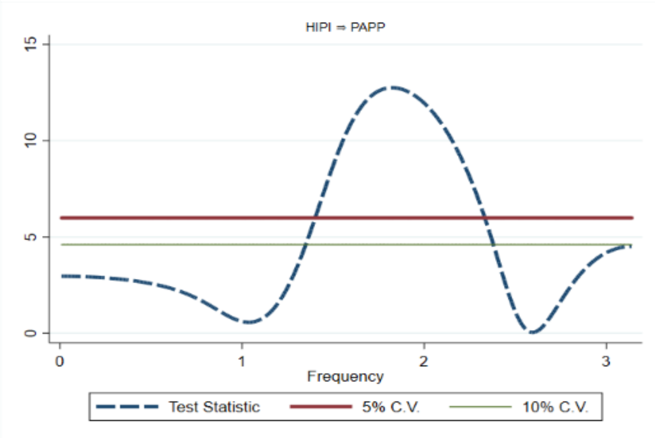
10% C.V.

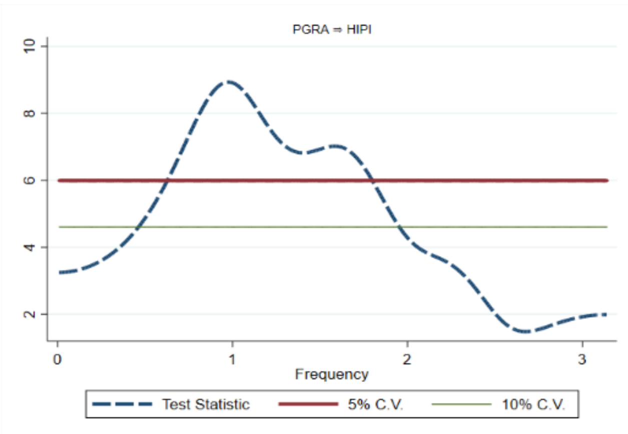

PGRA ⇒ EVI
Frequency
Test Statistic
5% C.V.
10% C.V.

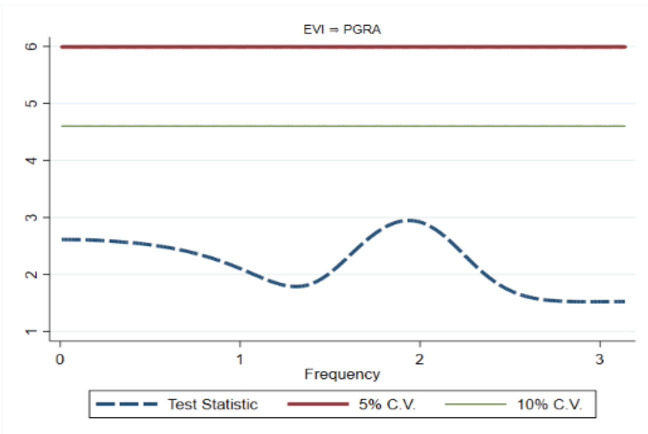

EVI ⇒ HIPI
Frequency
Test Statistic
5% C.V.
10% C.V.


HIPI ⇒ EVI
Frequency
Test Statistic
5% C.V.
10% C.V.


PAPP ⇒ HIPI
Frequency
Test Statistic
5% C.V.
10% C.V.


HIPI ⇒ PAPP
Frequency
Test Statistic
5% C.V.
10% C.V.


PGRA ⇒ HIPI
Frequency
Test Statistic
5% C.V.
10% C.V.


EVI ⇒ PGRA
Frequency
Test Statistic
5% C.V.
10% C.V.