

AN EMPIRICAL ANALYSIS OF THE DETERMINANTS OF INDIA'S HIGH-TECHNOLOGY EXPORTSMohd. FAYAZ¹Sandeep KAUR²

Abstract: The present study analyzed the determinants of high technology exports of India over the period 1980-2016 using cointegration and Granger causality procedures. The results indicate the existence of long-run equilibrium relationship for high tech exports of India with the said variables implying that Indian exports are influenced by these factors. Further Granger causality test reveals the direction of causality from technological activities, R&D, and world demand to high-tech exports. Hence, the results proved the significance of the world demand, FDI, and R&D in determining the high-tech exports of India. Thus there is a need to build an enabling environment for investments in high technology activities, and R&D expenditure should also be increased in technical innovations.

Keywords: India, Exports, Technology, FDI, R&D

1. Introduction

During the first three decades after independence, India's economic performance was quite disappointing, due to the misguided import substitution policies that closed the economy to international trade (Rodrik & Subramanian, 2004; Kohli, 2006; Fayaz & Bhatia, 2016). Since 1980, the removal of certain restrictions (such as license, permit, quotas etc.) and a turn towards a more open and free market, led a remarkable transformation in India (Kaur & Nanda, 2010). Consequently, on the back of various exports promotion schemes and other major economic reforms introduced in 1991, India's exports of goods and services indicated a notable increase in terms of value from a low of US\$ 11.4 billion in 1980 to US\$ 434.1 billion in 2016 and recorded a Compound Annual Growth Rate (CAGR) of 12.9 percent (Table 1). Meanwhile merchandise exports increased from US\$ 7.5 billion to US\$ 260.3 billion at a CAGR of 12.2 percent over the same period.

India's imports of goods and services has also increased from a low of US\$ 16.9 billion in 1980 to a high of US\$ 491.9 billion in 2015 at a rate of 12.2 percent and merchandise imports of India has increased from US\$ 13.8 billion in 1980 to US\$ 356.7 billion in 2016 at a rate of 12 percent. But the trade balance of India, both overall and merchandise, always remained in deficit owing to higher imports. Foreign trade is a primary connection of integration with the world economies and it plays an important role in the economic health of the country. India being a developing country is no exception to it. India's imports of goods and services, as a percentage of the world, has increased from 0.7 percent in 1980 to 2.4 percent in 2015 while its exports of goods and services, as a percentage of the world, has increased from 0.5 percent in 1980 to

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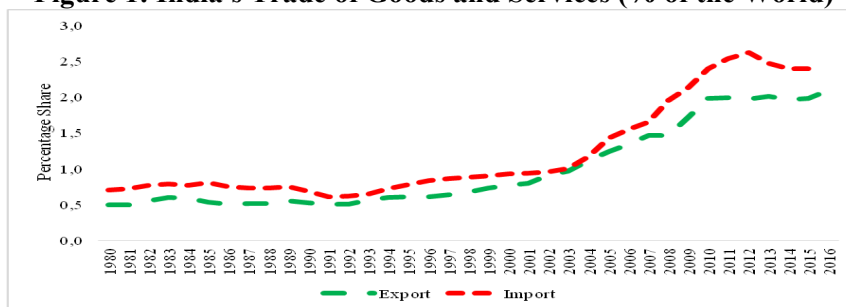
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2.1 percent in 2016 (figure 1). Considering the merchandise exports and imports, India's share has increased from around 0.4 and 0.7 percent to 1.6 and 2.2 percent respectively over the same period in the world merchandise exports and imports (figure 2). India even in the recent times of global slowdown, is deliberated to be one of the most stimulating markets for international trade.

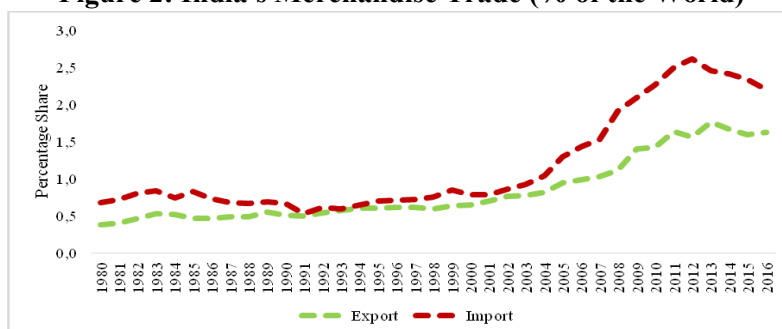
Table 1: India's Foreign Trade (US\$ Billion)

Year	Goods and Services			Merchandise		
	Export	Import	Trade Balance	Export	Import	Trade Balance
1980	11.41	16.93	-5.52	7.53	13.82	-6.29
1981	11.45	17.40	-5.95	7.88	14.46	-6.58
1982	11.97	17.52	-5.54	8.48	15.20	-6.72
1983	12.70	17.57	-4.87	9.46	15.28	-5.83
1984	13.29	17.86	-4.57	9.86	14.41	-4.55
1985	12.18	18.98	-6.80	8.99	16.22	-7.23
1986	12.90	19.63	-6.73	9.78	15.72	-5.94
1987	15.59	22.29	-6.70	12.09	17.15	-5.07
1988	17.85	25.41	-7.57	13.87	19.35	-5.48
1989	20.71	28.13	-7.42	17.05	21.72	-4.67
1990	22.57	29.53	-6.95	17.94	23.80	-5.86
1991	22.88	27.03	-4.16	17.90	19.51	-1.61
1992	25.41	29.67	-4.26	20.71	24.45	-3.74
1993	27.38	30.60	-3.22	22.24	23.30	-1.07
1994	32.27	37.87	-5.61	26.33	28.65	-2.32
1995	38.95	48.23	-9.27	31.70	36.59	-4.89
1996	40.68	54.96	-14.28	33.47	39.11	-5.64
1997	44.33	58.17	-13.85	34.79	41.43	-6.64
1998	46.29	59.37	-13.08	33.21	42.42	-9.22
1999	52.39	62.83	-10.44	36.67	49.71	-13.04
2000	60.70	73.08	-12.38	42.36	52.94	-10.58
2001	60.78	71.31	-10.53	43.88	50.67	-6.79
2002	73.23	75.74	-2.51	50.10	57.45	-7.36
2003	90.57	92.96	-2.39	59.36	72.43	-13.07
2004	126.27	130.98	-4.71	75.90	98.98	-23.08
2005	160.36	181.86	-21.50	100.35	140.86	-40.51
2006	199.38	225.09	-25.71	121.00	178.21	-57.21
2007	252.32	278.79	-26.46	146.00	218.65	-72.65
2008	288.04	379.48	-91.44	182.00	315.71	-133.71
2009	272.94	328.26	-55.32	177.00	266.40	-89.40
2010	374.24	439.06	-64.82	220.00	350.03	-130.03
2011	447.38	553.06	-105.68	301.00	462.40	-161.40
2012	448.40	579.91	-131.51	290.00	488.98	-198.98
2013	472.18	560.41	-88.23	337.00	466.05	-129.05
2014	468.33	553.55	-85.22	318.00	459.37	-141.37
2015	421.15	491.88	-70.73	264.00	390.74	-126.74
2016	434.06	-	-	260.33	356.70	-96.38
CAGR	12.9	12.2	-	12.2	12.0	-

Source: World Bank. Note: CAGR is compound annual growth rate

Figure 1: India's Trade of Goods and Services (% of the World)

Source: World Bank.

Figure 2: India's Merchandise Trade (% of the World)

Source: World Bank.

The analysis of exports has been a significant topic in the literature of economics over past few decades. However, in the recent past, a boom has been witnessed in the trade of high-technology goods. Emerging economies of the world are heavily engaged in the production of high-tech goods and reducing production costs for stimulating growth and exports. While developing countries have also no choice but to produce technology intensive goods. Thus the emphasis has turned to high-tech exports to comprehend the associations among high tech trade, innovation, and overall economic performance. In developed economies, the trade in technology-intensive products has substantially surged which suggests a significant gain from trade (Spulber, 2008; Tebaldi, 2011). Also high-tech exports has a significant impact on the growth of output (Falk, 2009). The trade of high-tech goods likewise provides evidence about the competitiveness in the global market of technology (Seyoum, 2005). However, the success of high technology exports heavily depends on the factors like inward FDI in sophisticated industries and a developed technological infrastructure. There is a wide range of variables in both theoretical and empirical studies. However, in the present study evolution of high technology intensive exports of India has been explained and for empirical analysis also, possible determinants of high technology exports are reviewed and estimated.

2. Methodology

The present study starts by describing the variables reported in Table 2 that reflect the main characteristics of the Indian high-tech exports.

Table 2: Description of Variables

Variable	Description	Units
HEX	Technological intensive exports	Ratio to merchandise exports
FDI	Foreign direct investment	Ratio to GDP
GCF	Gross capital formation	Ratio to GDP
IVA	Industrial Value Added	Ratio to GDP
RD	Research and development	Ratio to GDP
REER	Real effective exchange rate	Index (base: 2004-05)
TA	Technological activity	Number of patents granted
TO	Trade openness	Ratio to GDP
WD	World demand	Sum total of imports of all countries

The empirical validation of the model is carried out by estimating long-run relationship between the variables through cointegration test to check the long-run neutrality of the variables. While VECM is applied to analyze the short-run dynamics to check for the presence of overshooting phenomenon. Furthermore, to determine the direction of causality in the short-run, Granger causality is performed among the variables. The identified model consists of eight variables:

$$HEX = f(FDI, GCF, IVA, RD, REER, TA, TO, WD) \dots \dots (1)$$

The methodology is presented in the Annex.

3. Definition of the variables

- i. **High-tech Exports:** Exports let firms to produce on a big scale and in this manner exploit increasing returns to scale. The empirical evidence from the studies like Frankel and Romer, (1999); Samen (2010); Mishra *et al.*, (2011); Maity (2013), shows that exports contributes more and positively to economic growth. Many countries have successfully overcome the stagnation through raising exports (Sandhu & Ciocanel, 2014). The liberalization and integration of Indian economy with the world is being conceived as one of the main factors behind India's growth experiences in general and exports in particular. At the present time, when every single country is looking for viable way out for relaunching sustainable economic growth, the production of high-tech goods and their exports is equally relevant. Thus the present study, instead of nominal exports, considers technological intensive exports as a ratio to merchandise exports. Since both the medium-high and high-technology exports are capital and technology intensive, for the econometric estimates the medium-high technology exports have also been added to high-technology exports. Raiher *et al.*, (2017) also advocated the aggregation of both high and medium-tech sectors.
- ii. **Foreign Direct Investment (FDI):** Since, exports have been viewed as an engine of economic growth (Kwan & Kwok, 1995; Boltho, 1996; Deme, 2002; Maneschiold, 2008; Ahmed *et al.*, 2000; Kaur, 2011 & 2015), FDI plays an important role in the export performance of the host country. As it increases domestic capital as well as productivity of physical investment (Romer, 1986;

Lucas, 1998). Moreover, FDI transfer new technologies, marketing capabilities and managerial know-how by facilitating access to new and prominent foreign markets (Zhang, 2007; Majeed & Ahmad, 2007; Adhikary, 2011; Singh & Kaur, 2017). From this, a positive relationship between FDI and high-tech exports is presumed.

- iii. **Gross Capital Formation:** Gross Capital Formation (GCF) is one of the expenditure components of GDP. GCF together with net exports and final consumption serve as an indicator of the level of investment in an economy. GCF indicates a total outlay of physical capital used for investment purpose and it offers an actual representation of investment whereby goods and services are produced (Rajni, 2013). It promotes production in the country and thus affects the performance of exports from the supply side (Goldar, 1989; Barro, 1991; Ghali & Ahmed, 1999; Adhikary, 2011). There is a direct relationship between capital formation (investment) and exports because the development of investment policies is proved as an important determinant of economic growth and exports in the Newly Industrialized Countries (Md. & Suleiman, 2016). Thus the relationship between GCF and high-tech exports is likely to be positive.
- iv. **Industry Value Added:** The industry value added, also stand for gross domestic product (GDP), is the contribution of a government sector or a private industry to overall GDP. The studies like Dutta & Ahmad (2004), Hashim & Masih (2014), Ali *et al.*, (2016), Bakari & Mabrouki (2016) found a stable and long-run relationship between industrial value added and exports in case of developing countries.
- v. **Real Effective Exchange Rate (REER):** Real Exchange Effective Rate (REER) measures a country's goods in terms of value as compared to those of another country or a group of countries or the rest of world, at the persisting nominal exchange rate. The REER between two countries (say for example India and the US) is the product of nominal exchange rate (i.e., the rupee cost of a dollar), and the ratio of prices between the above said two countries. It is expressed by

$$REER = \frac{eP^*}{P}$$
 where e is nominal exchange rate of rupee-dollar, P^* is the average price of a good in the US and P is the average price of the good in India (Opoku-Afari, 2004). If countries trade in more than one commodity then usually economists measures the REER in terms of extensive basket of goods, as such basket generally takes the form of index number (such as WPI/CPI). The formula used for calculating REER in this study is as follows:

$$REER_{ust} = 100 * \left(\frac{NER_{ust}}{NER_{uso}} \right) * \left(\frac{IWPI_t}{WWPI_t} \right)$$

Where, $REER_{ust}$ is real effective exchange rate, NER_{ust} is nominal exchange rate of the rupee to US dollar for period t (current period), NER_{uso} is nominal exchange rate of rupee to the US dollar for period 0 (base period), $IWPI_t$ and $WWPI_t$ are whole sale price index of India and the world respectively for the period t . The reaction of exports to the movements in the REER can differ from country to country, as it takes into account the fluctuations in the prices of tradable and non-tradable goods and the consumption pattern differs across the countries. The expected relationship between REER and exports is negative

because as the REER of a country appreciates, the price competitiveness of its domestic producers is lost and thereby demand for its exports decreases (Aydin *et al.*, 2007; Cheung & Sengupta, 2013).

- vi. **Research and Development (R&D):** R&D relates to the activities that improve the existing products and procedures or direct towards the development of new products and procedures. In the contemporary industrial world, investment in R&D is an imperative source of technological development. As it is not only required for leading innovations but also for adapting and absorbing technology from external sources (Cohen & Levinthal, 1989). Further, with trade liberalization, it is important for industries to modernize their techniques in order to cut costs and compete with foreign manufacturers (Dani, 1992). Moreover, if R&D is leading to product diversity or the development of a new product, then export allows the country to realize economies of scale in the manufacture of this differential commodity (Parameswaran, 2010). Regarding the effect of R&D on exports, it has been found that increased R&D efforts are responsible for the increase in the export intensity of an economy (Lall, 2001; Aggarwal, 2004; Dutz & Dahlman, 2007; Chung, 2011; Goldar, 2013; Gupta *et al.*, 2013; UNCTAD, 2015). Thus the relationship between high-tech exports and R&D is expected to be positive.
- vii. **Technological Activities:** In the present era of globalization information technology is causing a significant shift in the demand for high technology goods and thus the composition of exports should be changed accordingly to realize sustainable export growth (Acharyya, 2007). The nexus between the technological activities and R&D are considered by some studies as substitutes to each other (for a survey see Parameswaran, 2010). While some others consider these two as complementary to each other like Soete (1981) defined R&D expenditure as technology input and technology activities (patents) as technology output. Montobbio & Rampa (2005) explained the role of only technological activities on the export performance of developing countries and of the view that there is an association between the growth of exports and technology. Countries having a higher degree of innovations and technology-intensive exports, relatively improved their importance in the world exports. Lall (1999, 2000) also claimed that technology played an important role in determining the trade pattern of developed as well as developing countries. In a liberalized trade policy regime, foreign technology can also be imported either in the form of capital goods representing recent technology or in intangible forms such as blueprints and designs. In this study, number of patents granted to India will be taken as a proxy for technological activities.
- viii. **Trade Openness:** Trade openness is expressed as the sum of exports and imports of goods and services to GDP ratio. It indicates an economy's degree of openness to trade, trade liberalization, receptivity of transfers related technology and the ability of a country to afford external debt with export earnings. Numerous Studies have empirically examined the influence of trade openness on technological advancement and economic growth (Cohen & Levinthal, 1989; Edward, 1993; Rodriguez & Rodrik, 2001). A relatively more open economy survive well in managing the external shocks through increased export

remunerations and easy external financing (Habib & Shah, 2003). Furthermore, it helps in engendering technological progress and productivity and thus an extensive bearing on the overall economic growth of an economy (Romer, 1990; Edwards, 1993). In the observation of Edwards (1998), less distorted and more open foreign trade region has an advantage in absorbing or reproducing the ideas produced in the rest of world. As trade liberalization enable international integration of production, technology diffusion and rise in efficiency. Trade openness is likely to be positively related to the high-tech exports.

- ix. **World Demand:** In order to establish a linkage between domestic policy changes and export growth, still, it is imperative to accentuate that the latter is determined not only by internal factors but also by external factors. Among external factors, world demand has been considered as one of the important determinants of country's trade performance (Roy, 2002; Veeramani, 2007; Veeramani, 2008; Shah, 2013). However, if the domestic policy milieu is highly restrictive, the country may not able to exploit the buoyancy of world demand. Likewise, even with the policy reforms, a country's exports may not grow more rapidly if the world demand happens to slow down in the post-reform period. The world demand is represented by the total of imports of all countries, and this necessarily would mean aggregate world demand (Muscatelli *et al.*, 1992; Roy, 2002; Roy, 2007; Shah, 2013).

4. Results and Discussion

The present section provides the results of empirical estimation of selected variables in view of the Indian high-tech exports. It is worthwhile to carry out a comprehensive analysis of the response of Indian exports to the variations in inducement structure bring about by the reforms. To explain the short-run as well as long-run association of exports with Foreign Direct Investment (FDI), Gross Capital Formation, (GCF), Industrial Value Added (IVA), Research and Development (R&D), Real Effective Exchange Rate (REER), Technological Activity (TA), Trade Openness (TO) and World Demand (WD), various econometric models have been used.

Before testing a causal relationship between the variables of interest, it is essential to check whether a series is stationary or non-stationary and also identify the integration order of the variables. The study used Johansen multivariate cointegration test to find out the long-run relationship between the concerned variables. But this test has some special properties, i.e., data must be integrated in the same order (Johansen, 1991). In this respect, the Augmented Dicky-Fuller (ADF) test (Dickey & Fuller, 1979) has been used to test the stationarity of the data so that the problem of spurious regression³ can be detected. Results of the ADF test has been reported in Table 3 which shows that all the variables are stationary after first difference.

The results reported in Table 3, in the Annex, confirmed that all the variables are I(1), i.e., stationary at first difference and fulfill the special property of cointegration test. Therefore, the Johansen cointegration test is performed to ascertain whether the

³ A significant relationship between the variables among which we are expecting no relationship.

variables taken in this study have a long-run relationship or not. First, the VECM lag length is selected on the basis of five alternate tests, viz., i) LR (sequential modified Lag Range test statistic), ii) FPE (Final Prediction Error), iii) AIC (Akaike Information Criterion), iv) SC (Schwarz Information Criterion) and v) HQ (Hannan-Quinn Information Criterion). Results of lag length criterion reported in Table 4, in the Annex, shows that LR and SC tests suggest that appropriate lag length must be equal to one (each test at 5% significance level).

Further to distinguish the cointegrating vectors among the multivariate system, Johansen proposed two statistics, i.e., Trace Statistic and Maximum Eigen Statistic. Results of both Trace statistic and Max. Eigen statistics, suggested by Johansen Cointegration test are given in Table 5, in the Annex, which determine that there are six cointegration equations in the system at five percent level of significance, which means that all variables influence technological intensive exports in the long-run.

However, there in the short-run may be a disequilibrium, and hence error term can be addressed as equilibrium error. The error correction mechanism, popularized by Engle & Granger (1987), states that if the presence of cointegration(s) is detected, then the Granger causality must be conducted in VECM. The error correction term (ECT) runs an additional channel through which causality can be identified. The short-run causality is proven by the joint significance of the coefficients of the lagged differenced variables while the long-run causality is established by the significance of the coefficient of ECT⁴. The result of VECM, in Table 6, in the Annex, shows that the coefficient of the ECT is correctly signed, i.e., negative and also statistically significant at the 5 percent level of significance for the first equation only. Which further indicates the presence of a long-run association between the variables of interest. Since ECT is negative and significant for only first equation, the long-run relationship has been estimated for the first equation only.

The normalized cointegrating vectors, representing the long-run relationship between the variables, have been reported in Table 7. While normalizing the assessed Coefficients, the signs must be reversed however that of the variable normalized residues same. The cointegration equation is said as;

$$HEX = 89.22 + 14.65WD + 2.21FDI + 11.49R\&D \dots \dots \dots (12)$$

The coefficients estimate on world demand, FDI and R&D are positive, statistically significant, and admittedly stronger, on high-tech exports of India. According to theory, such a positive relation between these variables is to be likely because an expansion in world demand, increased FDI, and R&D, necessarily be mirrored in the production and trade of a country. The results are in line with the empirical results of Goldar (1989) who also found world demand positively related to the exports of engineering goods from India. The studies such as Nayyar (1987); Roy (2002); Roy (2007); Veermani (2007); Shah (2013); Paul (2014), also found a positive impact of world demand, however, on the overall Indian exports. The literature on observing the determinants of high-tech exports in context of India is sparse. However, such positive

⁴ ECT in the VECM measures the pace of adjustments to its equilibrium in the long-run after a temporary shock.

impact of world demand on high-tech exports is echoed by some other studies focusing on the developed countries (Zhang, 2007; Tebaldi, 2011; Gökmen & Turen, 2013). Further, the coefficients on R&D are also positive and significant which signifies that high-tech exports strongly respond to R&D expenditure. Previous studies like Fagerberg (1995), Braunerhjelm & Thulin (2008), Sandhu & Ciocanel (2014) also reported quite strong support for a positive impact of R&D on the high-tech exports. While, the positive impact of FDI on Indian high-tech exports is consistent with the fact that high-tech industries necessitate huge investment funds and for developing countries like India, such funds are closely linked to FDI (Parlinggoman, 2017). This reveals that the utmost predictive and illuminating element belongs to inward FDI, particularly for a country with low technology capability. As, FDI is an important source of technology dissemination in developing countries (Archanum, 2002). Further, Transnational Corporations (TNCs) can transfer and diffuse technologies of many kinds through FDI. However, the dissemination of technology undertaken through externalized channels by non-equity forms is more important than undertaken through internalized channels (UNCTAD, 2010). Previous studies like Cheung (2010), Goswami & Saikia (2012), Gökmen & Turen (2013) have also shown a positive impact of FDI on the high-tech exports.

Table 7: Parameters in Normalized Cointegrating Vectors

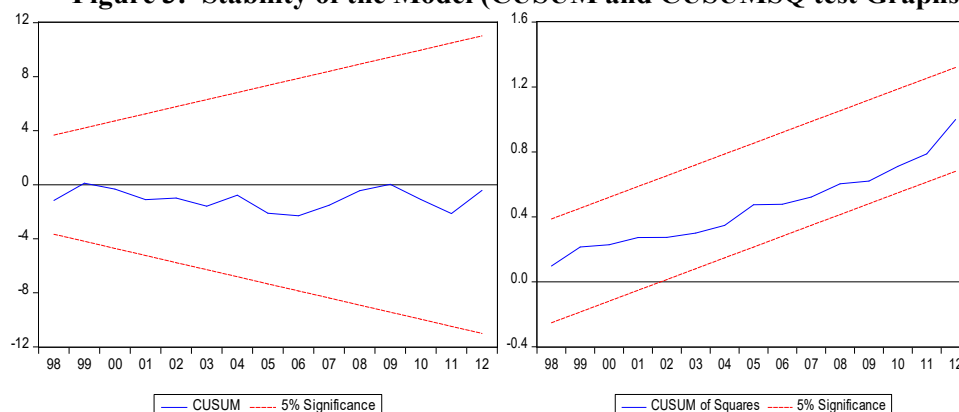
Variables	HE X	TO	GC F	TA	REE R	IV A	WD	FDI	R&D	Consta nt
Cointegrating Equation-1	1.00	0.0 0	0.00	0.0 0	0.00	0.0 0	- 14.653 7 (3.578 2) [0.000]*	- 2.2117 (1.232 2) [0.007]*	- 11.490 (3.384 5) [0.001]*	89.2253 3
Diagnostic test results										
			Jarque-Bera Test			Serial correlation LM test				
F-statistics			1.466659			3.128366				
P-value			0.480307			0.0987				

Source: Author's calculations. Note: * indicates significant at 5% level, Standard error in () & P-values in [].

To check whether the data is normally distributed or not and to check the problem of serial correlation and stability of the model, diagnostic tests have been used in this study and the results of these tests are given in Table 7 and figure 3. The first test used is Jarque-Bera test to ascertain the normality of data. The results of the test show a high probability value, and thus the null hypothesis i.e., the data is normally distributed, is accepted. The second test is Breusch-Godfrey serial correlation LM test to check the serial correlation concerning the variables. The null hypothesis for this test is that there is no serial correlation. The results of this test also show a high probability value and thus the null hypothesis is accepted. Thus it can be said that the data is normally distributed and there is no problem autocorrelation. Eventually, the stability of parameters has been tested by CUSUM and CUSUMSQ. The results of this test clearly

supported the stability of the parameters over the period of the study as the plots of both CUSUM and CUSUMSQ tests fall inside the critical bound of 95% confidence interval of stability (see Figure 3).

Figure 3: Stability of the Model (CUSUM and CUSUMSQ test Graphs)



As it is already confirmed that the data is stationary after first difference and the cointegration test also established the long-run relationship between the variables of interest, which is essential for causality test, here and now Granger causality test is applied. Because the causal linkages among the said variables are multisided and may be multidirectional. This test is important because it reports about the direction of the causality among the variables of interest. The results of Granger Causality reported in Table 8 shows bidirectional causality between technological activities (TA) and trade Openness (TO). While unidirectional causality has been detected between the world demand (WD) and FDI which means that an increase in world demand cause FDI and technological activities. The reason after this cause is that international trade openness facilitates technology diffusion from developed countries through imports and FDI, as these two are important channels of technology transfer and thus shift the production towards more technology-intensive products (Mehrra *et al.*, 2017). The studies like Piva (2003), Keller (2004), Meschi & Taymaz (n.d.), also showed that trade openness turned out to be a strategic conduit for technology adoption in developing countries. Unidirectional causality has been detected from technological intensive exports (HEX) to FDI. Further Granger causality test reveals the direction of causality from TA, R&D and WD to HEX and thus supports the specification that causality runs from the outlays on R&D, and technological activities to the export share. Several studies like Roy (2002), Seyoum (2005); Srholec (2007); Braunerhjelm & Thulin (2008); Tebaldi (2011); Sandhu & Ciocanel (2014) have also proved statistically the influence of the world demand, R&D and technological activities on the high tech exports.

5. Conclusion

The extensive efforts in the literature available on the present theme have been devoted to understand the impact of various determinants of exports in India. Drawing on the theoretical and empirical framework available in the literature, this study examined the relative response of high technology intensive exports of India to Foreign Direct Investment, Gross Capital Formation, Industrial Value Added, Research and Development (R&D), Real Effective Exchange Rate, Technological Activity, Trade

Openness, and World Demand, for the time period 1980 to 2016. The results indicate the existence of long-run equilibrium relationship for high technology intensive exports of India with the said variables implying that Indian exports are influenced by these factors. The study finds a positive and significant long-run relationship of high-tech exports with world demand, FDI, and R&D. Moreover, the results of the Granger Causality shows that there is a bidirectional causality between technological activities and trade openness. Unidirectional causality has been detected from high-tech exports to FDI. Further Granger causality test reveals the direction of causality from technological activities, R&D, and world demand to high-tech exports, and thus supports the specification that causality runs from the outlays on R&D and technological activities to the export share. Hence, the results proved the significance of the world demand, FDI, and R&D in determining the high-tech exports of India. Thus there is a need to build an enabling environment for investments in high technology activities, and R&D expenditure should also be increased in technical innovations. So that the competitiveness of Indian exports could be enhanced in the global trading environment thereby growth and development. As the technological advancements and diffusion in high-income countries appeared to be an overriding source of their trade patterns in technology-intensive products (Chen & Yang, 2005; Fu, 2005; Gani, 2009).

Table 8: Results of Granger Causality Test

Null Hypothesis:	F-Statistic	Prob.	Remarks
FDI does not Granger Cause HEX	0.05776	0.8116	Unidirectional
HEX does not Granger Cause FDI	5.72498	0.0228*	
GCF does not Granger Cause HEX	0.18550	0.6695	None
HEX does not Granger Cause GCF	0.09813	0.7561	
TA does not Granger Cause HEX	9.09906	0.0050*	Unidirectional
HEX does not Granger Cause TA	3.62788	0.1148	
R&D does not Granger Cause HEX	5.85393	0.0223*	Unidirectional
HEX does not Granger Cause R&D	0.00370	0.9518	
REER does not Granger Cause HEX	2.50979	0.1227	None
HEX does not Granger Cause REER	0.00370	0.9518	
TO does not Granger Cause HEX	1.75726	0.1941	None
HEX does not Granger Cause TO	0.66244	0.4215	
WD does not Granger Cause HEX	4.60081	0.0394*	Unidirectional
HEX does not Granger Cause WD	0.01063	0.9185	
IVA does not Granger Cause HEX	0.00398	0.9501	None
HEX does not Granger Cause IVA	1.31915	0.2590	
GCF does not Granger Cause FDI	15.4075	0.0004*	Unidirectional
FDI does not Granger Cause GCF	1.38609	0.2477	
TA does not Granger Cause FDI	3.21618	0.0824	None
FDI does not Granger Cause TA	0.00058	0.9809	
IVA does not Granger Cause FDI	4.89666	0.0342*	Unidirectional
FDI does not Granger Cause IVA	1.22315	0.2770	
R&D does not Granger Cause FDI	0.34324	0.5627	None

FDI does not Granger Cause R&D	0.00100	0.9750	
REER does not Granger Cause FDI	0.86226	0.3601	None
FDI does not Granger Cause REER	0.03807	0.8465	
TO does not Granger Cause FDI	2.21844	0.1462	None
FDI does not Granger Cause TO	0.74521	0.3944	
WD does not Granger Cause FDI	9.21068	0.0048*	Unidirectional
FDI does not Granger Cause WD	1.70344	0.2011	
IVA does not Granger Cause GCF	2.57680	0.1180	None
GCF does not Granger Cause IVA	0.68792	0.4128	
TA does not Granger Cause GCF	1.47380	0.2336	None
GCF does not Granger Cause TA	2.16478	0.1510	
R&D does not Granger Cause GCF	0.47503	0.4964	None
GCF does not Granger Cause R&D	0.04524	0.8331	
REER does not Granger Cause GCF	2.38936	0.1317	None
GCF does not Granger Cause REER	0.25089	0.6198	
TO does not Granger Cause GCF	0.52466	0.4740	Unidirectional
GCF does not Granger Cause TO	29.4849	0.0000*	
WD does not Granger Cause GCF	0.26341	0.6112	Unidirectional
GCF does not Granger Cause WD	5.43457	0.0260*	
WD does not Granger Cause IVA	1.62005	0.2120	None
IVA does not Granger Cause WD	2.53000	0.1212	
TA does not Granger Cause IVA	2.91582	0.0974	None
IVA does not Granger Cause TA	0.12943	0.7214	

Cont....

Null Hypothesis:	F-Statistic	Prob.	Remarks
R&D does not Granger Cause IVA	0.08994	0.7665	None
IVA does not Granger Cause R&D	0.27389	0.6049	
REER does not Granger Cause IVA	0.00160	0.9683	None
IVA does not Granger Cause REER	0.56783	0.4565	
TO does not Granger Cause IVA	3.38576	0.0748	Unidirectional
IVA does not Granger Cause TO	12.3209	0.0013*	
R&D does not Granger Cause TA	0.23332	0.6328	None
TA does not Granger Cause R&D	0.08905	0.7676	
REER does not Granger Cause TA	0.05841	0.8106	None
TA does not Granger Cause REER	0.01391	0.9069	
TO does not Granger Cause TA	7.24199	0.0112*	Bidirectional
TA does not Granger Cause TO	7.38429	0.0105*	
WD does not Granger Cause TA	3.19368	0.0834	None
TA does not Granger Cause WD	2.40768	0.1306	
REER does not Granger Cause R&D	0.28445	0.5980	None
R&D does not Granger Cause REER	2.23006	0.1465	

TO does not Granger Cause R&D	0.06460	0.0801	None
R&D does not Granger Cause TO	0.15692	0.6950	
WD does not Granger Cause R&D	0.00151	0.9693	None
R&D does not Granger Cause WD	1.19144	0.2843	
TO does not Granger Cause REER	0.14309	0.7077	None
REER does not Granger Cause TO	0.39049	0.5363	
WD does not Granger Cause REER	0.18096	0.6733	None
REER does not Granger Cause WD	2.82619	0.1022	
WD does not Granger Cause TO	1.18053	0.2851	None
TO does not Granger Cause WD	0.01063	0.9185	

Source: Author's calculations. Note 1: * and ** indicates significant at 5% and 10% level. Note 2: HEX is high and medium-high tech exports, REER is real effective exchange rate, GCF is gross capital formation, IVA is industrial value added, TA is technological activities represented by patents, TO is trade openness, and WD is world demand.

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Annex**a) Stationary Testing Procedures**

The aim of the study is to comprehend the impact of above-said variables in the long-run and short-run. For this purpose cointegration and error correction regression among the time series data will be applied. However, Johansen cointegration has some special properties i.e. data must be integrated in the same order (Johansen, 1991). For this reason, firstly the Augmented Dickey-Fuller (ADF) test, proposed by Dickey and Fuller (1979), is applied. The general framework of ADF test consists of the following equation.

$$\Delta Y_t = \alpha_0 + \beta_1 t + \gamma Y_{t-1} + \sum_{j=1}^m \beta_j \Delta Y_{t-j} + \varepsilon_t \dots (2)$$

Where, $\Delta Y_t = Y_t - Y_{t-1}$ and ε_t is a white noise error term and $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$, etc. The number of lagged differences is determined empirically.

b) Cointegration Procedure

Johansen test simultaneously determines the numbers of long run co-integrated equations in the system and provide coefficients of the long run causality (Gujarati *et al.*, 2012). Johansen (1991) multivariate cointegration test is used in this study to find the long-run relationship among the concerned variables. The initial point in the vector auto-regression (VAR) of order p is given by

$$Y_t = \mu + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \dots + \Pi_p Y_{t-p} + \varepsilon_t \dots (3)$$

In equation (3) $Y_t = FDI_t, GCF_t, IVA, RD_t, REER_t, TA_t, TO_t, WD_t$ is a 9×1 vector of variables and are integrated of order one i.e. $I(1)$ and ε_t is a 9×1 vector of

innovations. While Π_1 through Π_p are 9×9 coefficient matrices. The equation (3) contains unit root and can be parameterized by subtracting Y_{t-1} on both sides and the equation will be

$$\Delta Y_t = \mu + \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \dots + \Gamma_p \Delta Y_{t-p} - \Pi_p Y_{t-p} + \varepsilon_t \dots (4)$$

Where, $\Gamma_1 = \Pi_1 - I$, $\Gamma_2 = \Pi_2 - \Gamma_1$, $\Gamma_3 = \Pi_3 - \Gamma_2$ and

$\Pi = I - \Pi_1 - \Pi_2 - \dots - \Pi_p$. The matrix Π is called the impact matrix which determines the extent of cointegration. The above equation is rearranged as

$$\Delta Y_t = \mu + \Pi Y_{t-p} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \beta \mu_t + \varepsilon_t \dots (5)$$

Where Y is a p-dimensional process, while μ_t contains constant, a linear trend and seasonal dummies which are deterministic terms, $\Gamma_1's$ are $\rho \times \rho$ parametric matrices and β contain the parameters associated with μ_t (Johansen, 1991). The cointegrating vectors are given by β matrix and cointegrating vector entering each equation of the VECM, also known as the 'adjustment parameter' are given by α . This test utilizes two Likelihood Ratios (LR) test statistics for the number of cointegrating vectors. The two statistics are Trace test (J_{trace}) and Maximum eigenvalue (λ_{max}) test.

$$J_{trace} = -T \sum_{i=r+1}^N \ln(1 - \hat{\lambda}_i) \dots \dots (6)$$

$$\lambda_{max} = T \ln(1 - \hat{\lambda}_{r+1}) \dots \dots (7)$$

Where $\hat{\lambda}_i$ the estimated value for the i th is ordered eigenvalue from the matrix $\prod$ and T is the number of effective observations. The standard approach to the procedure of Johansen ML is to calculate first the Trace and Maximum Eigenvalue statistics and then compare these to the appropriate critical values. If a model consists of n different variables (like nine in case of the present study), we start by testing if we have one, two, three, four, five, six, seven, or eight cointegrating vectors.

c) Vector Error Correction Model

The Error Correction Mechanism (ECM) is firstly used by Sargan (1964) however popularized by Engle and Granger (1987). The model states that, if the presence of cointegration(s) is detected then, in the vector error correction model (VECM), the Granger causality must be conducted to examine the short-run relationship of all explanatory variables on GDP. If at least one cointegration vector is found among the number of variables, then there always exists an equating error correction representation which entails that change in the dependent variable can be formulated as a function of the fluctuations occur in other explanatory variables. Under these circumstances the basic structure of an error correction model system as follows:

$$\Delta Y_t = \alpha + \beta_0 \Delta X_{t-1} + \beta_1 ECT_{t-1} + \varepsilon_t \dots \dots (8)$$

Where Δ denotes first difference, ε_t is random error and ECT is the error correction term of the model which measures the speed of adjusting prior deviations from equilibrium.

Where,

$$ECT_{t-1} = HEX_{t-1} + \beta_1 EX + \beta_2 FDI + \beta_3 GCF + \beta_4 IVA + \beta_5 RD + \beta_6 REER + \beta_7 TA + \beta_8 TO + \beta_9 WD \dots \dots (9)$$

ECT_{t-1} is the error correction term which is derived from the cointegration equation of the long-run.

d) Granger Causality Test

Regression analysis, though essentially, does not imply causation, instead deals with one variable's dependence on the other, i.e. the long-run or short-run relationship of the variables does not validate the direction of influence or causality. Granger

(1969) and Sims (1972) introduced the Granger Causality test to the question, i.e., whether X causes Y and then to see whether the explanation can be improved by adding lagged values of X . If the coefficients are statistically significant on the lagged X 's or X assists in the prediction of Y , then Y is said to be granger caused by X . The frequent case is the two-way causation, i.e., ' Y Granger causes X ' and ' X Granger causes Y '. The test estimates the following pair of equations:

$$Y_t = \sum_{i=1}^n \alpha_i Y_{t-i} + \sum_{j=1}^n \beta_j X_{t-j} + u_{1t} \dots (10)$$

$$X_t = \sum_{i=1}^n \pi_i X_{t-i} + \sum_{j=1}^n \delta_j Y_{t-j} + u_{2t} \dots (11)$$

Where, disturbances u_{1t} and u_{2t} are assumed to be uncorrelated. In the above equations, since two variables, viz., X and Y , have been taken for instance, shows dealing with bilateral causality. Equation (10) postulates the relation of Y to the preceding values of itself as well as that of X , and a similar behavior of X is postulated by equation (11). There must be two cases of causality; i) *Unidirectional causality* from X to Y is proposed, if the projected coefficients in the equation (10), on the lagged X , are statistically different from zero as a group and in the equation (11) the set of estimated coefficients are not statistically different from zero on the lagged Y . ii) *Bidirectional causality* is indicated when the sets of estimated coefficients of X and Y in both the equations (10 and 11) are statistically significantly different from zero.

Besides above mentioned tests, imperative diagnostic statistics have also been applied, to ascertain the normality, autocorrelation, and stability of the model.

Table 3: Result of Augmented Dickey Fuller Test

Coefficient	At level			After first difference		
	t-statistic	Critical Value	Prob.	t-statistic	Critical Value	Prob.
HEX	0.950056	-2.945842	0.9951	-5.346374	-2.948404	0.0001*
FDI	-1.318255	-2.948404	0.6115	2.951125	-2.951125	0.0000*
GCF	1.427160	-2.945842	0.5583	-6.196049	-2.948404	0.0000*
IVA	-1.724444	-2.945842	0.4108	-5.765358	-2.948404	0.0000*
R&D	-2.531190	-2.960411	0.1183	-4.461170	-2.963972	0.0014*
REER	-2.275046	-2.945842	0.1852	-7.683303	-2.948404	0.0000*
TA	3.721598	-2.963972	1.0000	-6.336814	-2.951125	0.0000*
TO	-0.892048	-2.945842	0.7796	-5.133988	-2.948404	0.0002*
WD	-0.812608	-0.812608	0.8034	-6.693941	-2.948404	0.0000*

Source: Author's calculations

Note 1: * indicates significant at 5% level.

Note 2: HEX is high and medium-high-tech exports, REER is real effective exchange rate, GCF is gross capital formation, IVA industrial value added, TA is technological activities represented by patents, TO is trade openness, and WD is world demand.

Table 4: Lag Length Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-435.59	NA	60.28	29.63	30.06	29.77
1	-250.98	246.15*	0.076	22.73	26.93*	24.07
2	-117.83	97.64	0.014*	19.25*	27.24	21.81*

Source: Author's calculations

Note 1: * indicates lag order selected by the criterion

Note 2: LR Sequential modified LR test statistic (each test at 5% level), FPE is final prediction error, AIC is akaike information criterion, SC is Schwarz information criterion, HQ is hannan-quinn information criterion.

Table 5: Johansen Cointegration Test Results (Trace and Max-Eigen statistic)

Trace				Max-Eigen			
No. of Cointegrated Equations		Trace Statistic		No. of Cointegrated Equations		Max Eigen Statistic	
Null Hypothesis	Alternate Hypothesis	Trace Statistic	Prob.*	Null Hypothesis	Alternate Hypothesis	Max-Eigen Value	Prob.*
$r=0^*$	$r \geq 1$	358.2404 [197.3709]	0.0000	$r=0^*$	$r \geq 1$	90.96069 [58.43354]	0.0000
$r \leq 1^*$	$r \geq 2$	267.2797 [159.5297]	0.0000	$r \leq 1^*$	$r \geq 2$	85.66984 [52.36261]	0.0000
$r \leq 2^*$	$r \geq 3$	181.6099 [125.6154]	0.0000	$r \leq 2^*$	$r \geq 3$	51.07629 [46.23142]	0.0141
$r \leq 3^*$	$r \geq 4$	130.5336 [95.75366]	0.0000	$r \leq 3^*$	$r \geq 4$	43.40381 [40.07757]	0.0204
$r \leq 4^*$	$r \geq 5$	87.12981 [69.81889]	0.0011	$r \leq 4$	$r \geq 5$	32.75356 [33.87687]	0.0676
$r \leq 5^*$	$r \geq 6$	54.37625 [47.85613]	0.0108	$r \leq 5^*$	$r \geq 6$	28.22694 [27.58434]	0.0413
$r \leq 6$	$r \geq 7$	26.14931 [29.79707]	0.1243	$r \leq 6$	$r \geq 7$	15.97280 [21.13162]	0.2264

$r \leq 7$	$r \geq 8$	10.17651 [15.4947 1]	0.2674		$r \leq 7$	$r = 8$	10.17409 [14.2646 0]	0.2007
$r \leq 8$	$r = 9$	0.002415 [3.84146 6]	0.9586		$r \leq 8$	$r = 9$	0.002415 [3.84146 6]	0.9586

Source: Author's calculations

Note: * indicates rejection of the Null-hypothesis at the 5% level and ** indicates MacKinnon-Haug-Michelis (1999) p-values, and critical value in [].

Table 6: Results of Vector Error Correction Model

Variable	Coefficient	Std. error	t-statistic	P-value
Coint Eq 1 ECT(-1)	-0.718302	0.242936	-2.9567	0.0098*
Coint Eq 2 ECT(-1)	-19.9810.3	10.19138	-1.96058	0.0688
Coint Eq 3 ECT(-1)	0.126998	0.232098	0.547173	0.5923
Coint Eq 4 ECT(-1)	0.000331	0.001285	0.25794	0.8000
Coint Eq 5 ECT(-1)	0.007530	0.016975	0.443614	0.6637
Coint Eq 6 ECT(-1)	-0.387424	0.356841	-1.085706	0.2948
D(HEX)	0.417090	0.231114	1.804695	0.0912
D(TO)	17.00475	15.38229	1.105476	0.2864
D(GCF)	-0.024142	0.155207	-0.155547	0.8785
D(TA)	0.000506	0.001129	0.448598	0.6601
D(REER)	-0.015797	0.015252	-1.035757	0.3167
D(IVA)	0.643983	0.337330	1.909059	0.0756
D(WD)	-5.638675	4.942415	-1.140875	0.2718
D(FDI)	-1.094610	0.841419	-1.300909	0.2129
D(R&D)	-1.829417	2.171933	-0.842299	0.4128

Source: Author's calculations

Note: * indicates significant at 5% level.