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Linking GVC with Trade Dynamics between India and the United Kingdom: A Sector-Level Analysis

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Abstract

In the foreseeable future, the potential for deeper integration into the global value chain (GVC) between India and the UK lies within the establishment of a prospective free trade agreement (FTA). Such an agreement holds promise in facilitating market access, thereby fostering increased participation in the GVC for both countries. This study delves into nine specific sectors, carefully examining the factors that shape India's export flows to the UK within the framework of GVC. This research raises an important question: how will the trade dynamics evolve beyond tariff easing and trade liberalisation, emphasizing the development of robust value-added linkages between these sectors? The findings reveal the pivotal role of GVC participation in sectors like textiles, clothing, and base metals, increasing India's exports to the UK. Conversely, sectors like chemicals and pharmaceuticals thrive on factors such as intensive margin and research and development expenditure, augmenting export performance. These insights underscore the necessity for nuanced, sector-specific approaches in crafting trade policies and conducting FTA negotiations, unravelling the intricacies of trade dynamics between India and the UK, and laying the groundwork for mutually beneficial economic cooperation in the future.

Keywords: *Free Trade Agreements; GVC trade; Foreign Value Added; R&D Expenditure.*

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1. Introduction

India and the UK share robust historical and cultural connections. The year 2022 holds particular significance as India commemorates its 75th anniversary of Independence, coinciding with 75 years of bilateral ties between the two nations. Notably, the year 2004 marked a turning point in their relationship when the Strategic Partnership was established, leading to a deepening of their bilateral engagement. This partnership was initiated through a Joint Declaration titled "India-UK: Towards a New and Dynamic Partnership", which emphasized the importance of annual summits and frequent meetings between foreign ministers. Moreover, it highlighted the potential for collaboration in various domains, such as civil nuclear energy, space exploration, defence, counterterrorism, economic linkages, science and technology, education, and culture. The relationship was further elevated to an "Enhanced Partnership for the Future" in July 2010. The UK has been supportive of India's aspirations for permanent membership in the United Nations Security Council (UNSC) and has played a crucial role as an intermediary for India in its dialogues with the European Union (EU), G8, and other international organizations.

However, it was mainly Brexit that caused a big upheaval for the UK economy as it has been a part of the EU since 1973. This forced the UK to strengthen its trading relationships with partners beyond the EU and to target the most dynamic economies – of which a considerable number reside in the Indo-Pacific region. In this context, the UK government's "Global Britain" strategy, released in March 2021, laid out a noted shift towards the "Indo–Pacific" region leading to growth in geopolitical and economic significance over the next decade. This shift was further induced by the UK's changing relationship with China which majorly led UK's increasing involvement in the South China Sea. As a result, even in the midst of the pandemic, the UK was negotiating trade deals with many sectors as part of its new trade policy. The governments of the India and UK announced the "Enhanced Trade Partnership" (ETP) and their intention to negotiate a comprehensive free trade agreement. This has made the UK's relations with India paramount during recent times as further significant steps have been taken for the future of India-UK relations by signing the 2030 Roadmap.

This outlines the plans for the relationship over the next ten years which will focus on removing trade barriers and leading to more than doubling of India-UK trade by 2030, while including the consideration of an Interim Trade Agreement to deliver an "early harvest". Therefore, India-UK relations have been elevated based on a shared commitment towards democracy, fundamental freedom, and multilateralism. Howbeit, recently both nations have launched a vision for 2047 for shared security and prosperity for their people and the world. This mainly focuses on sustained economic recovery, building resilience, and trusted partnerships to assuage any external disruptions.

Even so at this juncture, with the US-China trade war, the COVID-19 epidemic, and the Ukraine conflict exacerbating each other's crises, the potential for supply chain shocks has never been more real. Global Value Chain integration at this point, therefore, calls for building sustainable and resilient GVCs where the rising delivery times along with the shortage of essential commodities have led to increasing discussions about re-shoring (and friend-shoring) in many countries. The signing of FTAs in this scenario will not only allow countries to build redundancies and diversified sources of inputs but will also ease market access. Also, in order to achieve the USD2-trillion export target by 2030, India's active participation in GVCs is essential. With 70 percent of the global goods and services exports coming from GVCs—they require close trade cooperation, lower duties, and efficient customs administration. An FTA ensures increased trade cooperation and lower duties. Additionally, the inclusion of new-age areas like digital trade in FTAs is a welcome step since digital technology continues to disrupt and transform GVCs (Gereffi & Lee, 2012; Gereffi & Fernandez-Stark, 2016; Kano, et al., 2020) by lowering entry barriers, increasing transparency, and facilitating collaborative networks.

There are studies that provide information regarding the trade relationship between India and the UK. Between 2000 and 2016, trade between the EU and India had grown 300 percent, while UK-India trade figures had remained largely static. Germany is India's largest trading partner in Europe, far surpassing the UK (Chaudhuri, 2020). However, their bilateral investment relationship is strengthened. As noted in (Demertzis & Roth, 2017), the UK is cumulatively the single largest source of FDI into India. Both countries view Brexit as an opportunity to deepen strategic trade relations (Ghanashyam, 2021). Even, India is the second largest FDI provider to the UK. For instance, Tata Steel has been one of the major investors in the UK and accounts for a turnover of over £40 billion per annum (Devonshire-Ellis & Savic, 2021). An FTA between the two economies will further reduce trade barriers, and hence stimulate investment, trade, and employment (Rinku & Niti, 2022). However, the discrepancy between the trade and investment relationship indicates India and the UK lack supply chain linkages—a sign that the two economies remain remarkably unintegrated despite a long-shared history (Chaudhuri, 2011). This paper thus provides an empirical investigation into the trade relationship between India and the UK from the perspective of GVCs in order to ascertain the factors that impact India's export to the UK for the identified nine sectors.

The objective of this paper, thus provides an empirical investigation into the trade relationship between India and the UK from the perspective of GVCs in order to ascertain the factors that impact India's export to the UK for the identified nine sectors. A crucial question is how trade dynamics will evolve beyond tariff easing and trade liberalisation, emphasizing the development of robust value-added linkages between these sectors namely textiles, wearing apparel, leather, coke, refined petroleum products, chemical and chemical products, pharmaceuticals, medicinal chemical, and botanical products, rubber and plastics products, basic metals,

electrical equipment, machinery and equipment and motor vehicles, trailers, and semi-trailers?

The paper presents the linkage between GVC participation and trade between the sectors by utilising advanced panel-time series from 1995 to 2018. This sheds light on the diverse sectors, describing their long-term patterns of cointegration among the factors and establishing causation between these pairs of factors.

2. Literature Review

The literature emphasizes that the rise of GVCs may generate greater demand for deep preferential trade agreements with partner sectors in order to facilitate intermediate goods trade across national borders (Lawrence, 1996; Antràs & Staiger, 2012). Furthermore, a different body of literature (Baier & Bergstrand, 2007; González, 2012; Johnson & Noguera, 2012; Johnson, 2014; Johnson & Noguera, 2017; Laget, et al., 2020) emphasises the role of trade agreements in promoting trade, including value-added trade, and finds some evidence of a favourable relationship between the two. Studies (Li & Yu, 2021; Kee & Tang, 2016; Liu, et al., 2019, Zhang et al., 2021, Zeng et al., 2021) on the effect of PTAs on GVC integration in the setting of Asia have usually been produced evidence that is consistent with the aforementioned conclusions.

It has been suggested indirectly in key studies by (Lawrence, 1996; Baldwin, 2011) among others, that the rise of deep trade agreements and the rising prominence of GVCs are related. It makes intuitive sense that the unbundling of production phases across borders will result in new types of cross-border policy spillovers and issues with timeliness. Greater levels of integration may help with these issues of commitment and coordination by enforcing the national regulations required for GVCs to function properly. Moreover, prior research on the implications of PTAs for economic welfare (Wei & Frankel, 1996; Krueger, 1999; Baier & Bergstrand, 2007; Goldstein et al., 2007; Yarbrough & Yarbrough, 1994) and more recent studies of the impact of PTA design on trade flows.

With the two-sided arguments in place, the objective of this paper is to understand the bilateral trade relationship between India and the UK from the point of view of value addition. Integration in the form of participation in larger regional and global markets offers many opportunities to raise productivity. Simply looking at the evolution of exports may misrepresent the international competitive position of a country. This is because sectors with more diversified exports at the higher end of the quality spectrum tend to grow faster, by capitalising on their comparative advantages to boost export growth while creating jobs (Amiti & Freud, 2008; Broda & Weinstein, 2008; Funke & Ruhwedel, 2001; Hausmann et al., 2007; Hummels & Klenow, 2005, Raei et al., 2019). Hence, it is crucial to understand the effect of participation in GVC on the value of exported products, especially given the rise in the share of globally traded intermediates. We discuss the export performance of

India and the UK along the value chain by distinguishing upstream activities (i.e. the production of intermediate inputs) and more downstream activities (e.g. the final assembly of products) of different sectors.

Several studies state that the trade of intermediate inputs accounts for a considerable portion of international trade (Johnson, 2014; Johnson & Noguera, 2017; Koopman et al., 2014; Los et al.,2016), reflecting the growing fragmentation of production processes across borders and reinforcing the multiregional interdependence of the production and trade structure.

So, this paper extends the existing studies in two important ways. First, to the best of our knowledge, this is the first study that analyses the factors that affect India's export flows to the UK from the lens of GVC participation for nine sectors, namely; textiles, wearing apparel, leather, coke and refined petroleum products, chemical and chemical products, pharmaceuticals, medicinal chemical and botanical products, rubber and plastics products, basic metals, electrical equipment, machinery and equipment and motor vehicles, trailers and semi-trailers. The paper presents the linkage between GVC participation and trade between the sectors by utilising advanced panel-time series from 1995 to 2018. This sheds light on the diverse sectors, describing their long-term patterns of cointegration among the factors and establishing causation between these pairs of factors. Second, it will aid in understanding the potential of the industrial value chain between India and the UK and possible areas of further trade cooperation. The third section of the paper focuses on trends and patterns of bilateral trade, also including intra-industry trade and GVC participation and position index. Sections four and five explain the research methodology and the application of the model. Finally, sections six and seven discuss the results and conclusion.

3. India-UK Trade: Trends and Patterns

As of 2021, India held the 12th position among the UK's trading partners, ranking 20th as an export destination and 12th as an import source. India accounted for 1.9 percent of all UK trade, with 1.3 percent attributed to exports and 2.4 percent to imports in goods and services. Recognizing the significance of their bilateral trade, both nations initiated FTA negotiations in January 2022, aiming to conclude most talks by October 2022. Presently, UK exports to India face a 19 percent average tariff, far higher than the 2 percent levied on US exports, highlighting the potential for trade liberalization.

A successful FTA with India could give UK companies a competitive edge over US and EU counterparts by providing preferential access to the Indian market, enhancing exporting prospects, and deepening economic ties. Seeking to reduce reliance on China, the UK sees an opportunity for India to increase its share in areas where China dominates, like fashion, homeware, electrical machinery, and industrial machinery.

Drawing from recent agreements with Singapore and Japan, the UK may negotiate concessions on similar products in the India-UK FTA.

In services, the UK aims to gain market access in sectors like communication and technology, offering significant opportunities for exporters. The FTA has the potential to nearly double UK exports to India, increase total trade by up to USD 33 billion annually by 2035, and boost UK wages by USD 3.62 billion.

While annual trade between the UK and India is already impressive at £24 BN, a realistic goal of £50 BN over the next ten years is a step towards a better UK-India partnership (DIT, 2021). India's total trade with the UK has although reduced from USD17 BN in 2013 to USD13 BN in 2020. However, the trade surplus has been positive (as can be seen from Figure 1).

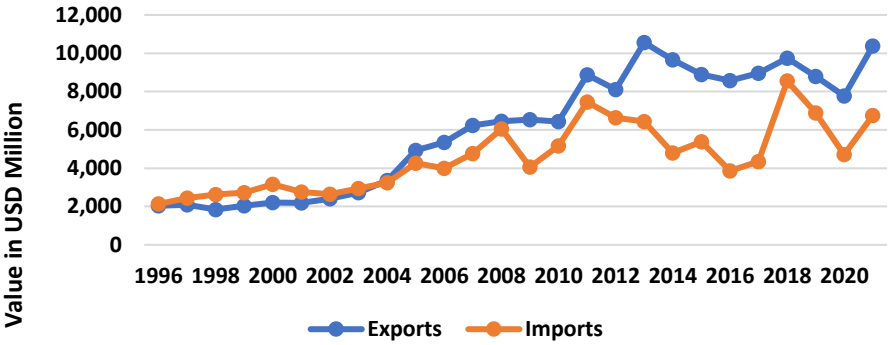

Figure 1. India's trade with the UK
Source-WITS

Table 1. India's Exports to the UK in USD Million (Top 5 sectors)

HS Code	Product Description	2005	2010	2015	2020	Growth (2005-2020) %
84	Machinery, mechanical appliances	288.7 (5.8)	361.5 (5.6)	678.6 (7.6)	653.3 (8.4)	2.5
61	Articles of apparel and clothing	351.0 (7.1)	458.4 (7.1)	897.5 (10.1)	588.3 (7.6)	0.5
30	Pharmaceutical products	125.8 (2.5)	281.5 (4.4)	457.7 (5.1)	563.6 (7.3)	7.3
62	Articles of apparel and clothing accessories	582.6 (11.7)	742.9 (11.5)	909.1 (10.2)	533.9 (6.9)	-3.5
71	Gems & Jewellery	246.9 (5.0)	338.9 (5.3)	522.6 (5.9)	526.5 (6.8)	2.1
India's total Exports to the UK		**4958.9**	**6436.4**	**8889.8**	**7767.6**	**3.04**

*Source- ITC Trade Map [in **( )** is the percent share]*

Table 2. India's Imports from UK in USD Million (Top 5 sectors)

HS Code	Product Description	2005	2010	2015	2020	Growth (2005-2020) %
71	Gems & Jewellery	2107.7 (49.0)	1519.9 (29.4)	1582.3 (29.4)	862.5 (18.3)	-6.4
84	Mechanical Machinery	477.0 (11.1)	773.5 (15.0)	699.5 (13.0)	809.9 (17.2)	3.0
85	Electrical machinery	234.5 (5.5)	352.1 (6.8)	348.9 (6.5)	391.2 (8.3)	2.8
90	Optical, photographic,	138.4 (3.2)	191.0 (3.7)	268.9 (5.0)	277.0 (5.9)	4.1
72	Iron and steel	351.5 (8.2)	463.2 (9.0)	423.0 (7.9)	226.8 (4.8)	-3.5
India's total Imports from UK		**4300.4**	**5166.8**	**5379.0**	**4710.8**	**0.61**

*Source- ITC Trade Map [in **( )** is the percent share]*

Considering the top traded products between the India and UK, from Table 1 and 2, it can be seen that India's top five exports to the UK account for around 40 percent of India's total exports to the UK, and imports account for 55 percent of India's total imports from the UK. This reflects the concentration of the product basket from India's point of view. The sectors having both high exports and imports were machinery, electrical machinery, and cotton and apparel. India primarily imported gems and jewellery, mechanical and electrical machinery, and iron steel from the UK in 2020. While it exported machinery, pharmaceutical products, clothing, and gems to the UK.

3.1. Intra-Industry Trade

Intra-industry trade index between two countries refers to the extent to which they trade in similar products (Krugman, 2000). So, the higher the index, the greater the increase in trade of similar products belonging to a particular sector. The idea of global production fragmentation has risen as a result of the development of more affordable and dependable transportation and communication technology, with regional groups being essential to profitability. And this explains the huge increase in trade within industries (Akram, 2013). Even in products with comparable factor input requirements, differences in the level of technology and human capital result in intra-industry competition (Grubel & Lloyd, 1975). According to (Yeats, 1998) intra-industry trade accounts for about 30 percent of all manufactured commodities traded globally.

Table 3 shows the main tradable sectors between India and the UK from 1995 to 2020 and the sector-by-sector level of intra-industry trade between the two countries. The intra-industry trade between the two countries has gradually increased during the past 15 years. However, for certain sectors like pharmaceuticals, organic chemicals, plastics, articles of iron and steel, and automotive, the IIT index has either decreased or stayed the same in the year 2020.

Table 3. Sector-wise Degree of Intra-Industry Trade between India and the UK

HS Codes	Product Description	1995	2000	2005	2010	2015	2020
71	Gems & Jewellery	0.23	0.12	0.21	0.36	0.50	0.76
30	Pharmaceutical	0.22	0.46	0.26	0.25	0.20	0.22
27	Minerals	0.01	0.06	0.00	0.47	0.61	0.64
84	Mechanical Machinery	0.37	0.64	0.75	0.64	0.99	0.89
87	Automotive	0.86	0.77	0.14	0.47	0.36	0.43
29	Organic chemicals	0.77	0.96	0.79	0.67	0.44	0.49
62	Art of apparel & clothing access, n	0.00	0.00	0.01	0.01	0.02	0.01
61	Art of apparel & clothing access,	0.01	0.00	0.01	0.02	0.01	0.01
63	Other made-up textile articles; set	0.08	0.05	0.03	0.04	0.05	0.03
85	Electrical Machinery	1.00	0.73	0.86	0.90	0.93	0.92
39	Plastics and articles thereof	0.70	0.91	0.87	0.86	0.89	0.67
73	Articles of iron or steel	0.98	0.53	0.43	0.53	0.38	0.48
38	Miscellaneous chemical products	0.38	0.52	1.00	0.97	0.91	0.96
76	Aluminium and articles thereof	0.34	0.75	0.58	0.27	0.31	0.36

Source: Authors' calculations.

The trend majorly focuses on the structure of the trade pattern between the two countries over the years. Next, we examine each country's position and involvement in GVCs. The gems & jewellery, minerals, machinery, mechanical appliances, nuclear reactors, boilers, as well as articles of clothing and clothing accessories that are not knit or crocheted, plastic, iron and steel and miscellaneous chemicals have consistently and significantly high index values.

3.2. GVC Participation and Position

Trade increasingly flows through GVCs, where firms in one country produce or import intermediate products to sell to firms in other countries while adding value along the chain. This worldwide fragmentation enables countries to specialize in various tasks related to production, such as manufacturing intermediates or final assembly (OECD, 2012, González 2012). Participation in value chains can occur through backward or forward involvement, or both, with examples including importing raw materials to create finished goods (backward) or exporting raw materials for further processing by trading partners (forward).

Using the Eora Multi-Region Input-Output (MRIO) database, the value-added content of gross exports can be divided into forward GVC participation (domestic value added in intermediates exported and re-exported) and backward GVC participation (value added of inputs imported for production). Analysing GVC participation and position in India and the UK from 1995 to 2018 reveals shifts in their roles within value chains. India's participation increased but leaned more toward downstream activities, indicating increased import of inputs, while the UK saw growth in both participation and position (from Figure 2).

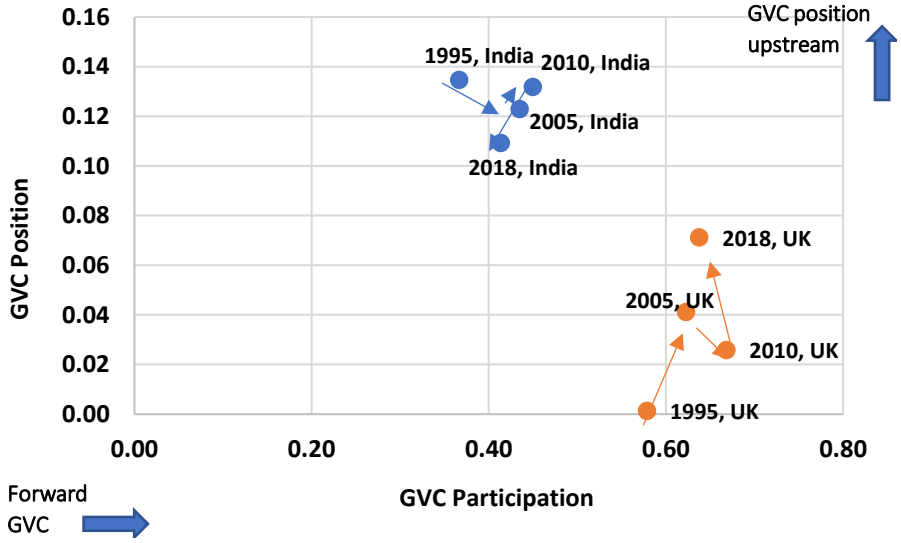

Figure 2. Country-Wise Participation in global value chains

Source: Authors' calculation based on the EORA Database

In GVCs, each nation's involvement in product creation is minimal, focusing solely on value addition. Examining bilateral trade reveals contrasting trends and patterns in trade fragmentation. India's contribution to UK exports increased steadily, while the UK's contribution to Indian exports remained relatively consistent. Both countries' domestic value addition as a percentage of total exports followed similar trajectories, suggesting a production-sharing agreement to enhance trade complementarities.

Table 4. Share of Value Addition in Exports (%)

GVC Indicators	1995		2005		2010		2018	
	India	**UK**	**India**	**UK**	**India**	**UK**	**India**	**UK**
Domestic Value Addition	77	71	75	68	74	66	76	67
UK VA in India's Exports	1.14		1.17		1.16		0.88	
India's VA in UK Exports		0.08		0.18		0.23		0.27

Source: EORA database (UK-United Kingdom, VA-Value Addition)

This paper delves into the developmental aspect of the proposed FTA within the context of GVCs, highlighting the bilateral GVC participation between India and the UK. It explores how trade dynamics have evolved and whether they will further strengthen through robust and supportive value-added linkages, beyond tariff easing and trade liberalization in these sectors.

Access to GVCs has enabled sectors to enhance their technological capabilities, albeit with varying outcomes across countries and sectors. Integration into GVCs has altered the development trajectories of many sectors, facilitated by the removal of political barriers to trade and foreign investment. Decreasing trade costs, driven by reductions in transportation and communication costs, have prompted multinational corporations (MNCs) to globalize their production processes world (Foster-McGregor et al., 2015; Grossman & Rossi-Hansberg, 2008). In today's landscape, production is fragmented into distinct stages of value-creating activities performed in cost-efficient locations worldwide. The rise of GVCs has generated a substantial body of literature suggesting that firms, through GVC participation, gain crucial opportunities to access international markets, specialize in core tasks, procure higher-quality inputs, and leverage new ideas and technologies, thereby stimulating productivity growth and expanding export volumes (Lall, 2000; Collier & Venables, 2007; Criscuolo & Timmis, 2017; Pahl & Timmer, 2019).

In recent decades, the proliferation of regional trade agreements (RTAs), preferential trade agreements (PTAs), and FTAs has closely paralleled the increasing fragmentation of global production through GVCs. FTAs, in particular, are designed to decrease or remove trade barriers, thereby fostering international trade. These agreements typically focus on a core chapter that offers preferential tariff treatment. Additionally, they often encompass provisions related to trade facilitation and rulemaking across various domains, including investment, intellectual property, government procurement, technical standards, and sanitary and phytosanitary issues.

4. Research methodology and variable description

4.1. Methodology Description

The variables considered may not be stationary because the data in the form of 9 sectors and 24 years is longer than the cross-section units, but I(1) and the model is most likely dynamic. In this case, the panel-ARDL (Autoregressive distributed lag) model suggested by (Pesaran & Smith, 1995; Pesaran et al., 1999) will be more useful. The panel ARDL model is used instead of other dynamic panel methods like fixed effects, instrumental variables, or GMM estimators proposed by (Anderson & Hsiao, 1981; Arellano & Bover, 1995), which can produce inconsistent estimates of the average value of the parameters unless the coefficients are identical across sectors. The approach for panel data analysis is mostly determined by a preliminary understanding of the qualities of the variables being studied. We begin with a cross-sectional dependence test, followed by a panel unit root test to ensure that the variables are stationary, thereafter, panel cointegration tests, long-run estimation approach, and panel causality test are all performed.

4.1.1. Cross-Sectional Dependence (CSD) test

There is a possibility of common correlation and shocks between sectors in studies employing panel data analysis across sectors. It occurs primarily when the sectors in question are linked locally or worldwide. The hypothesis of cross-sectional independence is problematic in macroeconomic analysis in this context, as Urbain and Westerlund (2006) explain because economies are highly interconnected. This is verified by using the Breusch and Pagan (1980) LM test, Pesaran (2004) CD, and Pesaran (2004) scaled LM test in a cross-sectional dependency analysis.

4.1.2. Panel Unit Root Tests

The panel unit root test of stationary is the second test. As macroeconomic variables are included in our research, non-stationarity of the variables is a possibility. Therefore, examining the order of integration of the variables under investigation is critical for developing a long-term relationship between them. When cross-sectional dependencies are present, the traditional first-generation unit root tests are unreliable and produce biased results. As a result, the presence of unit root is tested using Im et al. (2003) cross-sectionally augmented Im, Pesaran, and Shin unit root test (CIPS) and Pesaran's cross-sectional augmented Dickey-Fuller unit root test (CADF), (2007). These tests can reduce the impact of cross-sectional dependencies and provide accurate results estimation. The CIPS and CADF tests are both conducted with the null hypothesis of non-stationarity of the variables versus the alternative hypothesis of otherwise.

The following expression is used to calculate the CADF unit root test statistic.

$$\Delta y_{i,t} = \alpha_i + \beta_i Y_{i,t-1} + C_i Y_{i,t-1} \sum_{j=0}^{S} d_{ij} \Delta Y_{i,t-j} + \sum_{j=1}^{S} \delta_{ij} \Delta Y_{i,t-j} + \varepsilon_{i,t} \quad (1)$$

Where $\bar{y}$ and $\Delta\bar{y}$ denote the cross-sectional averages of the lagged and first differences respectively. The CIPS unit root test statistic is generated from the CADF regression model through t-statistic, which is as follows:

$$\mathrm{CIPS} = \mathrm{N}^{-1} \Sigma^{\mathrm{N}}{}_{\mathrm{i}=1} \mathrm{CADF}_{\mathrm{i}}$$

After this, panel cointegration analysis is performed.

4.1.3. Panel cointegration tests

The next phase in the empirical research is to look at long-run relationships between the variables using Westerlund's (2005) second-generation panel cointegration test, which is based on the Durbin–Hausman principle. The method is valuable because it can handle cross-sectional interdependence and variability in data in a way that first-generation conventional panel cointegration tests can't. The test also doesn't require any adjustments to account for the data's temporal dependencies. It is used for a mix of $\mathrm{I}(1)$ and $\mathrm{I}(0)$ variables since it does not require prior knowledge of the sequence of integration of variables.

The following autoregressive model based on residuals of initial panel regression (Equation 5) is used to test the null hypothesis of no cointegration:

$\hat{\vartheta}_{it} = \rho_i \hat{\vartheta}_{it-1} + \mu_{it}$

Where,

$\hat{Z}_{it} = \sum_{j=1}^{t} \hat{\vartheta}_{it}$ and $\hat{R}_{it} = \sum_{j=1}^{t} \hat{\vartheta}_{it}^{2}$

4.1.4. Panel long-run estimates

After confirming that variables are cointegrated, a group of panel estimators is used to estimate the long-run and short-run relationship. We used three estimators that considered slope heterogeneity and cross-sectional dependence. Mean Group (MG), Pooled Mean Group (PMG), and Dynamic Fixed Effect (DFE) estimators are the three options. The first is the Mean Group (MG) estimator established by Pesaran and Smith (1995), which incorporates a regression model that is applied independently for each panel unit and then the average of the individual coefficients to generate a mean group estimate. Pesaran et al. (1999) used the PMG approach to estimate the short-run and long-run parameters of the Panel Error Correction Model (PECM) using the Autoregressive Distributed Lag (ARDL) approach. Weinhold (1999) proposed the DFE estimator, in which the slopes are fixed but the intercepts are permitted to fluctuate across nations.

The model estimated has the form of an $\mathrm{ARDL(p,q,q,\ldots,q)}$ model

$$\mathrm{GE}_{it} = \sum_{j=1}^{p} a_{ij}\mathrm{GE}_{i,\,t\text{-}j} + \sum_{j=0}^{q} \delta_{ij}' X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (2)$$

Where X is the vector of explanatory variables. Reparametrizing the model, it turns into:

$$\Delta\mathrm{GE}_{it} = \varphi_i(\mathrm{GE}_{i,t-1} - \beta i' Xit) + \sum_{j=1}^{p-1} a_{ij}^{*}\,\Delta\mathrm{GE\_Part}_{it\text{-}j} + \sum_{j=0}^{q-1} \delta_{ij}^{*}\,'\Delta Xi,t-j + \mu i + \varepsilon it \quad (3)$$

Where the βi is the vector of interest measuring the long-run impact of the explanatory variables on gross exports and φi is the error corrector mechanism impact. The short-run coefficients are the last set of parameters. The disturbances are distributed independently across time and units, with a constant mean and variance within each unit.

The Hausman's test is used to evaluate which of the three estimators is the best. The null hypothesis (Ho) of the Hausman Test between MG and PMG is that both are consistent, but MG is inefficient when compared to the alternative hypothesis (H1) that PMG is consistent. When comparing PMG to DFE, the Ho is that DFE is inefficient, whereas PMG's H1 is consistent. Finally, using Hausman selection criteria, the results are analysed to choose the best model.

4.1.6. Robustness Check

In addition, as part of the robustness analysis, we used Fully Modified Ordinary Least Square (FMOLS) (Pedroni, 2001), in predicting long-run relationships for heterogeneous panels, FMOLS is widely employed to correct biases from the data. A non-parametric technique is used in the FMOLS method.

4.1.7. Panel Causality Test

Having established the long-run relationship between the variables, the causality test by Dumitrescu and Hurlin (2012) is conducted which is suited for heterogeneous panels, like the one incorporated in our study. This test is used when N is growing, and T is constant. Moreover, it can also be used when T>N and when N>T. This test assumes that there is no cross-sectional dependency. Yet, the Monte Carlo simulations show that even under the conditions of cross-sectional dependency, this test can produce strong results. This test is used for balanced and heterogeneous panels.

$$y_{it} = \sum_{k=1}^{k} \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^{k} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t} \quad (4)$$

Here, K stands for the lag length. Moreover, the panel for the test is a balanced panel. $\gamma i^{(k)}$ which is an autoregressive parameter, and $\beta i^{(k)}$, which is the regression coefficient pitch can change among the groups. In addition to these, the tests do not have a random process. This test is a fixed one and has a fixed coefficient model.

4.2. Descriptive Statistics

The variables selected for this paper are taken to understand certain aspects of the India-UK trade relations which correspond to the trade complementarity in the trade pattern of the two countries through which important sectors are identified. Further, the role of intra-industry trade in bilateral trade relations is examined to provide the extent of engagement between the sectors. Finally, the extent of value addition between the countries is witnessed through global value chain participation and the position of the sectors concerned. The research hypothesis is therefore to ascertain the impact of GVC participation on India's sectoral exports to the UK.

The panel data is taken for the period 1995–2018 and for nine different sectors namely textiles, wearing apparel, leather, coke and refined petroleum products, chemical and chemical products, pharmaceuticals, medicinal chemical and botanical products, rubber and plastics products, basic metals, electrical equipment, machinery and equipment and motor vehicles, trailers and semi-trailers where the selected time period enables to develop linkages between trade through GVCs, thus predicting the co-integration (long-run relation) among the selected variables. As the data for value-added variables is obtained from UNCTAD-EORA, GVC Database-OECD TiVA (2020), it is seen that the latest available data is until 2018.

The variables are selected for the study based on the existing literature and theories. The variables have been accessed from various sources for the 1995–2018 period as the value-added data is available until 2018 globally from the database of OECD-WTO: Statistics on Trade in Value Added- TiVA (OECD, 2018). The data for gross exports, and backward and forward participation has been taken from the OECD TiVA Database (OECD, 2020). The data for margins has been taken from the UNComtrade-WITS Database, whereas the data for R&D expenditure has been taken from the CMIE (Centre for Monitoring Indian Economy) industry outlook. The variables considered are as follows.

Gross Exports (GE)—is taken as the dependent variable. Firms perform exports to become more competitive and earn greater revenues. This results in making firms more efficient due to knowledge spillovers (Wagner 2007). India's export to the UK as a proportion of India's total exports to the world for the respective sectors has been taken. Export data is accessed from the TiVA database.

GVC participation: Backward linkages (BLs) and Forward Linkages (FLs)—*t*o examine the interlinkage between trade, technology, investment, and GVC participation, it is important to break down gross trade flows to origins of value-added (Koopman et al., 2014). Participation in value chains could occur through either backward participation forward participation or through both. Backward participation would imply importing semi-processed or primary products, adding value to produce a consumable or processed product, and exporting it for further value addition or final consumption. Forward participation would imply exporting primary products, such as metal ores, agricultural products or textile raw materials, and less processed material for value addition by the trading partner (Hummels et al., 2001; Arora & Siddiqui, 2020; 2022, De Marchi, et al., 2020, Arora, 2023).

Intensive Margins (IM)—Recent studies underscore the crucial role of the intensive margin in trade dynamics (Bernard et al., 2009; Besedes & Prusa, 2011; Brenton & Newfarmer, 2007; Helpman et al., 2008). The intensive margin pertains to the growth of trade stemming mainly from existing trade flows rather than new ones, reflecting the extent of technology utilization within countries, industries, or firms. Additional research (Battisti et al., 2004) emphasizes the significance of the intensive margin in explaining the growth of technological usage.

Extensive Margins (EM)—provide an indication of specialisation and diversification of exports. Extensive margin refers to the literature on the adoption and diffusion of new technology (Battisti et al., 2004; Comin et al., 2006). Few Studies emphasise the importance of extensive margins in explaining the growth of trade volumes (Hummels & Klenow, 2005; Arora & Siddiqui, 2020).

Bilateral Revealed Comparative Advantage (BRCA)—compares the relative strengths of two countries in trade with each other. It analyses whether a particular product or sector is relatively more important in the exports of one country compared to its trading partner. BRCA analysis provides insights into the

specialization patterns and competitive advantages of countries in their trade relationships with each other (Balassa, 1977). In this paper, India's exports to the UK have also been estimated through BRCA.

R&D Expenditure (R&D)—the endogenous growth models considered the generation of new knowledge through investment in R&D as the major source of technical progress and, hence, growth (Romer, 1990). India, for such a long time, has been making efforts to promote technological advancement through indigenous or imports of R&D and technology (Basant, 1997). The impact of technological capability measured in terms of R&D effort on the export performance of the firms belonging to India's high-technology sectors has shown significant results. R&D intensity is found to be statistically significant in explaining India's export performance in low-and medium-technology industries (Kumar & Siddharthan, 1994) and even for MSMEs in general in highlighting the relevance of R&D resources involving innovation and technology orientation in achieving superior export performance, especially in the form of ICT infrastructure readiness and capabilities (Arora & Siddiqui, 2022).

The data set has both temporal and spatial components, resulting in a panel data structure. The model can be written as follows, based on the foregoing theoretical discussion:

$$GE_{it} = \beta_0 + \beta_1 BLs + \beta_2 FLs_{it} + \beta_3 IM_{it} + \beta_4 EM_{it} + \beta_5 BRCA_{it} + \beta_6 R\&D_{it} + \varepsilon_{it} \quad (5)$$

GE_{it} represents India's gross exports to the UK in year t. The estimated regression coefficients of export and import variables, as well as other important variables, range from β_0 to β_6, and it is the error component of the regression equation ε_{it}, which includes sectoral-specific fixed effects and time-specific effects.

The correlation coefficient matrix, shown in Table 5 reveals the direction and intensity of correlations between any two continuous variables. The signs of the Pearson correlation coefficients, r, with respect to the dependent variable are mixed. Both forward linkages and bilateral RCA witness a positive correlation with gross exports.

Table 5. Correlation Matrix

Variables	GE	BLs	FLs	IM	EM	BRCA	R&D
GE	1	-0.3	0.03	-0.09	-0.04	0.28	-0.11
BLs	-0.3	1	-0.57	0.1	0.27	-0.025	-0.25
FLs	0.03	-0.57	1	-0.3	-0.34	-0.25	0.3
IM	-0.09	0.1	-0.3	1	0.056	0.65	-0.06
EM	-0.04	0.27	-0.34	0.056	1	-0.098	-0.046
BRCA	0.28	-0.025	-0.25	0.65	-0.098	1	-0.024
R&D	-0.11	-0.25	0.3	-0.06	-0.046	-0.024	1

Table 6 presents the summary statistics focussing on average values for all the sectors and years.

Table-6 Summary Statistics (Mean Values)

Variables	GE	BLs	FLs	IM	EM	BRCA	R&D
Mean	0.03	0.24	0.63	0.038	0.041	1.65	0.06
Median	0.02	0.22	0.57	0.03	0.03	1.23	0.05
Maximum	0.15	0.73	1.52	0.14	0.1	11.7	0.15
Minimum	0	0.09	0.1	0	0.01	0.03	0
Std. Dev.	0.02	0.11	0.23	0.029	0.022	1.74	0.03
Observations	216	216	216	216	216	216	216

5. Empirical Analysis and Results

Table 7 summarises the findings of the cross-dependence investigation. As the sectors under consideration are interconnected internationally and associated culturally, historically, and geographically, there is a significant possibility of cross-sectional dependence among selected variables. For testing cross dependencies, we use the LM test of Breusch and Pagan (1980), the CD test of Pesaran (2004), and the Scaled LM test of Pesaran (2004). At a 1% significance level, we reject the null hypothesis of no cross-sectional dependencies in each example. The findings reveal that all of the variables display significant variation across cross-sections. This demonstrates that the variables have cross-sectional dependence.

Table 7. Cross-sectional dependence test result

Variable	Breusch Pagan LM	Pesaran Scaled LM	Pesaran CD
GE	580*	64*	23*
BLs	448*	48*	19*
FLs	90*	6.4*	1.19*
IM	216*	21**	10.2*
EM	248*	25*	-2.8*
R&D	324*	33*	3*
BRCA	158*	14*	0.14*

*Note: *p ≤ 0.01, **p ≤ 0.05*

Second-generation panel unit root tests, such as CADF and CIPS, are applicable due to the presence of cross-dependence among the variables. Both tests can deal with the problem of cross-section dependence. The CADF and CIPS panel unit root tests are presented in Table 8. Few of the variables are stationary at the level and I(1) for both CADF and CIPS. The Westerlund cointegration test requires this criterion.

Next, the second-generation cointegration test based on the Durbin-Hausman technique is analysed. The test is used to look at the long-term association between the variables. The variance ratio (VR) test is performed on three different cointegrating equation specifications. For the null hypothesis of no cointegration, Westerlund (2005) developed a pair of VR test statistics. The alternative hypothesis in one variation of the Westerlund test is that the variables are cointegrated in some of the panels.

Table 8. CADF and CIPS panel unit root test result

	CADF				CIPS			
	Level		First difference		Level		First difference	
Variable	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend
GE	-0.276	-14.44	-0.276	-14.44	-0.429	-3.39		
BLs	-0.78	-3.7	-0.78	-3.7	-0.69	-0.066		
FLs	-0.789	-2.49	-0.789	-2.49	-1.43	-2.53	-2.94	-3.06
IM	-1.83	-0.99	-1.83	-0.99	-0.05	-1.39	-2.89	-2.89
EM	-1.17	-2.66	-1.17	-2.66	-1.29	-2.99	-3.89	-3.5
R&D	2.33	-4.17	2.33	-4.17	0.65	-1.92	-4.09	-4.11
BRCA	-3.27	-3.21	-3.27	-3.21	-1.43	-1.41	-3.21	-3.48

Note: In Bold- The test indicates that the variable is stationary at 5%.

The test results in Table 9 indicate that we reject the null hypothesis of no cointegration at a 10% significance level and accept the alternate hypothesis in both circumstances when the null hypothesis is rejected. We conclude that the Durbin-Hausman cointegration tests are valid and indicate that at least one cointegrating vector exists in the prototype. We can deduce from these findings that there is a valid equilibrium relationship in the long run.

Table 9. Westerlund test for cointegration

	With Trend		With Demean		With Demean & Trend	
	Variance Ratio	**p-value**	**Variance Ratio**	**p-value**	**Variance Ratio**	**p-value**
Ho is No cointegration, and H1 some panels are cointegrated	0.25	0.39	1.33***	0.09	1.04***	0.1

*Note: * p ≤ 0.01, ** p ≤ 0.05, ***p ≤ 0.1*

PMG-ARDL (1,1,1,1,1,1,1) model has been calculated. Long-run coefficients are implied in the first portion of the table. As can be seen from Table 10, in the long run, intensive margin and R&D expenditure positively and significantly impact India's gross exports to the UK. GVC participation captured in terms of backward linkages also positively impacts gross exports, but it is not significant. However, the impact of forward linkages, BRCA, and extensive margin on gross exports has come out negative. India has a comparative advantage in a significantly larger number of sectors than the UK. After the India-UK FTA, it has been estimated that the UK's imports from India will increase by around 12 percent per annum, and the maximum increase would occur for articles of apparel and clothing along with footwear and mechanical appliances which have a very high duty applied duty of around 12 percent (Banga, 2017). Therefore, with the reduction of tariff rates, the impact of BRCA on gross exports can become positive in the long run. By further looking at the sectoral trends, we witness that in the short run, for textile and clothing and

machinery and equipment, GVC participation positively impacts gross exports of India to the UK. The bilateral export competitiveness (BRCA) of all these products except for textile and clothing, positively and significantly impacts gross exports.

Table 10. Panel ARDL Model Result (Sector-wise)

Variable	Textiles, wearing apparel, leather	Coke and refined petroleum products	Chemical and chemical products	Pharmaceuticals, medicinal chemical and botanical products	Rubber and plastics products	Basic metals	Electrical equipment	Machinery and equipment	Motor vehicles, trailers and semi-trailers
ECT (-1)	-0.003 (0.65)	0.12 (0.16)	0.01 (0.42)	-0.28 (0.00*)	-0.18 (0.05**)	-0.01 (0.54)	-0.02 (0.31)	-0.07 (0.02**)	-0.01 (0.64)
BLs	0.07 (0.17)	0.05 (0.98)	-0.03 (0.55)	-0.02 (0.91)	-0.26 (0.41)	0.13 (0.03**)	-0.22 (0.12)	0.01 (0.8)	-0.17 (0.28)
FLs	0.03 (0.11)	-0.02 (0.00*)	-0.02 (0.00*)	-0.05 (0.00*)	-0.18 (0.40)	-0.02 (0.24)	0.02 (0.05***)	0.01 (0.82)	0.13 (0.02**)
IM	0.69 (0.00*)	-0.19 (0.51)	-0.34 (0.01**)	0.05 (0.00*)	-1.65 (0.03**)	-0.58 (0.03**)	-0.99 (0.00*)	-0.09 (0.49)	-1.83 (0.10)
EM	-0.07 (0.84)	0.15 (0.62)	0.05 (0.00*)	-0.69 (0.37)	0.05 (0.00*)	-0.29 (0.40)	0.13 (0.5)	0.05 (0.00*)	-0.74 (0.0**3)
BRCA	-0.01 (0.01**)	0.00 (0.20)	0.05 (0.00*)	0.05 (0.00*)	0.02 (0.00*)	0.02 (0.00*)	0.02 (0.00*)	0.05 (0.67*)	0.02 (0.03*)
R&D	0.07 (0.68)	-2.83 (0.58)	0.94 (0.00*)	-2.36 (0.00*)	1.68 (0.34)	-0.56 (0.04**)	-0.35 (0.70)	0.05 (0.99)	0.94 (0.10)
C	-0.02 (0.00)	-0.01 (0.5)	-0.05 (0.163)	-0.053 (0.163)	-0.34 (0.16)	0.005 (0.56)	-0.003 (0.8)	-0.02 (0.00)	0.015 (0.126)

*Note: * p ≤ 0.01, ** p ≤ 0.05, ***p ≤ 0.1 (p-values are in the parenthesis)*

The support of R&D expenditure performed in these sectors further positively impacts gross exports, particularly for sectors like textile and clothing, chemical and chemical products, rubber and plastic products, machinery equipment's, and for motor vehicles. Shifts in positioning and diversification into new sectors (IDR, 2016a), knowledge and technology transfer in the form of technology imports from FDI partners and increased in-house R&D capability are all factors that contribute to successful technological up-gradation in GVCs.

The short-run relationship is seen in the lower half of the tables (Table 10). The error correction term (ECT) yields the short-run dynamic adjustment results. Because the ECT coefficient is statistically significant, cointegration among the variables in the panel is also statistically significant. We can observe that the error correction coefficient is negative and significant at the 5% level, any deviation from the long-run equilibrium is adjusted in the short run at an 8 percent adjustment speed. The expected sign of the error term is also negative, implying that any departure from

the long-run relationship will return to equilibrium in the following period. Similar outcomes may be found in all of the MG and DFE variants.

5.1. Robustness Check

Long-run coefficients can be determined using evidence of cointegration. The long-run coefficients can be calculated using a variety of econometric methodologies. We used FMOLS to assess the robustness of the PMG model in this scenario. Table 11 shows the results of the FMOLS test. Because of the high Adjusted R2 value, the model's explanatory power is quite strong. With this, the sign of the coefficient is also consistent with both the theory and the PMG model results.

Table 11. FMOLS (Dependent Variable-Gross Exports)

Variable	All	Textiles, wearing apparel, leather	Coke and refined petroleum products	Chemical and chemical products	Pharmaceuticals, medicinal chemical and botanical products	Rubber and plastics products	Basic metals	Electrical equipment	Machinery and equipment	Motor vehicles, trailers and semi-trailers
BLs	-0.11 (0*)	0.012 (0.76)	-0.03 (0*)	-0.05 0.29	-0.44 0.035**	-1.47 (0*)	-0.102 (0*)	-0.84 (0*)	0.29 (0*)	-0.54 (0*)
FLs	-0.058 (0*)	0.016 (0.1)	-0.005 (0.142)	-0.01 (0.05**)	-0.03 (0.45)	-0.7 (0*)	0.02 (0.83)	-0.62 (0*)	0.136 (0.013**)	-0.15 (0.15)
IM	0.63 (0.06***)	0.768 (0.12)	0.188 (0.17)	-0.065 (0.5)	8.69 (0.17)	-2.87 (0.11)	-1.23 (0*)	0.57 (0.08***)	0.06 (0.63)	1.02 (0.69)
EM	1.422 (0*)	0.83 (0.11)	-0.04 (0.77)	1.24 (0.13)	-4.66 (0*)	-14.56 (0.1)	0.67 (0.03**)	0.167 (0.632)	-2.76 (0.049**)	-0.309 (0.67)
BRCA	0.001	-0.05	0.05	0	0.55	-0.012	0.018	-0.012	0.002	0

*Note: * p ≤ 0.01, ** p ≤ 0.05, ***p ≤ 0.1 (p-values are in the parenthesis)*

The results show that GVC participation, in the long run, is strengthened with the knowledge created through expenditure on R&D by these sectors. As a result, we can conclude that the PMG is a reliable model for determining the long and short-term relationships between gross exports and GVC participation, trade margins, BRCA, and R&D expenditure. FMOLS estimating methodology supports a similar conclusion.

Finally, we investigate the causal link between the selected explanatory and control variables. The long-run coefficients calculated with PMG and FMOLS, only show the relationship's direction and outcome. They are, however, not suitable for establishing any form of causal relationship. The findings of the heterogeneous pairwise Dumitrescu-Hurlin Panel Causality Tests to assess the causal nexus between the variables under investigation are presented in Table 10.

Table 12 below shows important causality results. It shows that backward linkages unidirectionally cause gross exports. Gross exports uni-directionally cause both

intensive and extensive margins, bilateral RCA, and R&D expenditure. Therefore, the strength of GVC participation in impacting the bilateral trade relation between India and the UK is witnessed.

Table 12. Pairwise Dumitrescu-Hurlin panel causality test (Lags: 2)

Variables	GE	BLs	FLs	IM	EM	BRCA	R&D
GE		0.41	0.77	0.03**	0.03**	0.03**	0.6*
BLs	0.10***		0.89	0.94	0*	0.45	0.26
FLs	0.43	0.98		0.77	0.65	0.9	0.43
IM	0.32	0.75	0.86		0.6	0.10***	0.46
EM	0.18	0.12	0.44	0.5		0.33	0.51
BRCA	0.85	0.87	0.67	0.79	0.65		0.38
R&D	0.93	0.91	0.5*	0.02**	0.7	0*	

*Note: * p ≤ 0.01, ** p ≤ 0.05, ***p ≤ 0.1*

When trade and technology variables are incorporated in GVCs, both direct and indirect linkages between them enable functional upgrading. When a firm's technology upgrading trajectory suggests process improvement, it may change from assembly to manufacturing, beginning to incorporate a bigger share of self-produced or locally sourced components with an increase in capabilities (Kaplinsky, 2015). Therefore, for India, all these sectors with different base of technological capabilities and with the help of fragmentation of production processes can further reap the benefits through trade once India and the UK deepen their trade relations through FTA which focuses on complementing their export competitiveness.

6. Conclusion and Policy Implications

Both of these nations have set an ambitious goal for bilateral trade in products and services to reach USD100 billion by 2030. Even while India only represents 0.6 percent of the UK's inward FDI stock and barely 2 percent of its goods and services imports, the potential for growth on both of these fronts is enormous and far more than with any other country. Additionally, the FTA is believed to immediately provide both sides with major economic benefits. More than 90 percent of tariff lines may be covered by the agreement, which is likely to be a comprehensive one (an earlier plan called for an interim agreement first). Moreover, it might result in a surge in services trade between the UK and India, which now accounts for 60 percent of the total annual trade between the two nations. This FTA being termed a new-age and modern FTA involves broader issues such as labour, climate/environment, digital technology, public procurement, supply chains, e-commerce, gender, health, education, and even some evolving sectors, in addition to the traditional pillars. Albeit this agreement goes beyond the exchange of trade concessions—they are designed to enable a stronger position for India in the GVCs.

We have included the merchandise side for this paper and the result from the model indicates that for the high-technology sectors (OECD, 2011) such as chemical and chemical products and pharmaceuticals, medicinal chemicals, and botanical

products the GVC participation linkage with gross exports has come out to be negative, however, the association is not significant. Further, the competitiveness of the trade positively boosts India's gross exports to the UK for these sectors. It is for the chemical sector that the expenditure on R&D and extensive margin positively impact gross exports and for the pharmaceutical sector, intensive margin positively impacts the gross exports. Therefore, the support from technology is needed to strengthen the bilateral trade. For textiles, wearing apparel, and leather (low-technology sector), the GVC linkages have a positive relation with gross exports. In fact, the path-dependence nature of exports measured in terms of intensive margin also has a positive and significant association with gross exports. The expenditure on R&D also plays a major role in boosting exports in predicting the market trend, quality control, and building a brand as well as in managing it, (Arora & Siddiqui, 2020; 2022). The impact of R&D on gross export has come out to be positive in this case. For the base metals and rubber and plastics products (medium low-technology sectors), the role of BRCA in boosting exports significantly has come out positive. For motor vehicles, trailers, and semi-trailers sectors, the forward linkages have a positive and significant relation with gross exports. This positive relationship is also witnessed for BRCA and R&D expenditure with gross exports.

The pairwise causality shows a positive relation of all the factors with gross exports, however, the backward participation causes gross exports to be significant for all the sectors concerned. R&D expenditure significantly causes forward linkages and intensive margins. Further, intensive margin significantly causes BRCA, thus strong linkage is witnessed between GVC participation, gross exports, BRCA, trade margins, and R&D expenditure—underpinning the fact that for both India and the UK, the combination of factors are at play in strengthening the trade relationship which is supported by the FTA looking at trade more holistically which reflects the changing paradigm of international economic relations.

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Appendix

1. Trade Complementarity Index

The TC between countries k and j is defined as:

$$TC_{ij} = 100(1 - \frac{\sum |m_{ik} - x_{ij}|}{2})$$

Where x_{ij} is the share of good i in global exports of country j and m_{ik} is the share of good i in all imports of country k. (We have taken it for different sectors)

2. Sectoral Intra-Industry Index

$$Sectoral\ GLI_{sij} = 1 - \frac{\sum s|M_{sij} - X_{sij}|}{\sum s\left(M_{sij} + X_{sij}\right)}$$

Where sectoral GLI_{sij} represents the sectoral Grubel-Llyod index of Intra-industry trade between countries i and j.

Ms_{ij} represents the imports of sectors by country i from j.

Xs_{ij} represents the exports of sectors by country i to j.

The index zero represents pure inter-industry trade in the given sector and one indicates pure intra-industry trade in a given sector.

3. Bilateral RCA

A bilateral RCA above one tells that for that particular good country i has a revealed comparative advantage in the country j's market, compared with the rest of the world, which is computed as follows:

$$\mathrm{BRCAk_{ij}} = \mathrm{Xk_{ij}/X_{ij}} \mid \mathrm{Xk_{wj}/X_{wj}}$$

Where Xk_{ij}, X_{ij} are the country i's export of goods k and its total export to country j, respectively. Xk_{wj}, X_{wj} is the world's export of goods k and the world's total export to country j. A value of this index smaller than once again reveals a comparative disadvantage but in country j, while an index above one represents a comparative advantage in country j.

4. Intensive and Extensive Margins

$$IM = \sum X_{ij} / \sum X_{wj}$$

$$EM = \sum X_{ij} / \sum X_{w}$$

where, x=exports,

i= exporting country,

j= sector of interest,

w=the world,

5. GVC Participation

$$GVC_{Participation} = \frac{FVA + DVX}{Gross\ Exports}$$

6. GVC Position

$$GVC_{Position} = \ln(1 + \frac{DVX}{Gross\ Exports}) - \ln(1 + \frac{FVA}{Gross\ Exports})$$