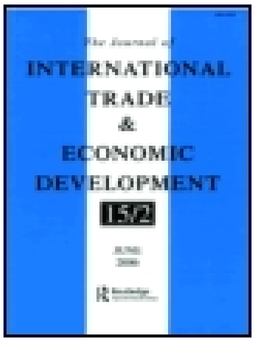

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ABSTRACT

This paper examines whether linking into Global Value Chains (GVCs) can facilitate product upgrading in developing country firms, enabling them to climb up the value-chain ladder. The analysis is conducted using an unbalanced panel of Indian manufacturing firms in the period 2001–2015. Extensive data at the product-firm level is used to construct a sales-weighted average product sophistication level of Indian firms. To account for econometric issues of endogeneity and self-selection, the study employs the System GMM estimator and Propensity Score Matching (PSM). Findings indicate that linking into GVCs boosts the average product sophistication level of Indian firms by roughly 2 percent. Younger, more innovative, and more embedded GVC firms capture higher product sophistication gains from GVCs, while no significant impact is found for foreign investment. Results are robust to the use of different measurement techniques, model and lag specifications and methodologies. Findings suggest that designing trade policies in developing countries to increase GVC integration can enable product upgrading but there is a need to boost internal innovative capabilities to maximise gains from linking into GVCs. Further, the study raises important concerns regarding the future of export sophistication in India, demonstrating a shift in India's GVC trade towards the Global South and its tendency to export less sophisticated goods to Southern partners.

KEYWORDS Product sophistication; global value chains; India; manufacturing

JEL CLASSIFICATIONS F14, F15, O12

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1. Introduction

The production of highly sophisticated goods shifts out the technological frontier of a country, helping it to improve growth performance and climb up the export value chain (Hausmann, Hwang, and Rodrik 2007; Hausmann and Rodrik 2003). In line with this, a rising body of trade literature has documented a positive link between export sophistication and economic performance, with important contributions by Rebelo and Silva (2017) for Portugal, and Boschma and Iammarino (2009) and Coniglio, Lagravinese, and Vurchio (2016) for Italy. Analysing determinants of export sophistication have been the crux of many studies in new trade theory and development economics. Several

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factors have emerged as drivers of export sophistication, including trade regimes and international production networks (Amiti and Freund 2010; Yu and Hu 2015), foreign direct investment (Jarreau and Poncet 2012), and human capital (Fang, Gu, and Li 2015). An emerging strand of literature has also identified participation in global value chains (GVCs) as a driver of export sophistication (Flores and Vaillant, 2011; Betai and Chanda 2020; and Ndubuisi and Owusu 2021). GVCs can facilitate technology transfer, knowledge spillover, and access to cheaper and higher quality intermediate inputs (Criscuolo and Timmis 2017; Pahl and Timmer 2020).

However, much of the evidence on export sophistication is based on country-level data, with little known about micro-level drivers of product upgrading. The existing firm-level studies on product upgrading tend to focus more on product innovation. The empirical evidence demonstrates a 'learning by importing' effect; imported intermediates have led to product innovation in India (Goldberg et al. 2010a) and Taiwan (Lin and Lin 2010), and fostered product quality upgrading for Chilean manufacturing firms (Fernandes and Paunov 2013) and Chinese firms (Khandelwal, Schott, and Wei 2013). In the case of exporting, there exists a two-way relationship between innovation and firm-level export behaviour. On the one hand, exposure to international buyers enables access to new technologies and higher competition for supplier firms, creating incentives to innovate (Almeida and Fernandes 2008). This has been as evidenced in the case of manufacturing firms in Italy (Bratti and Felice 2012) and for rug producers in Egypt (Atkin, Khandelwal, and Osman 2017). On the other hand, innovative capabilities at the firm-level can increase firms' probability to export (Caldera 2010; Azar and Ciabuschi 2017).

Simultaneously exporting and importing in global value chains (GVCs) can create cost complementarities which can be re-invested into new product lines. In line with this, Şeker (2012) finds that two-way traders are the most innovative, in terms of both product and process innovation than any other group of firms. A positive impact of linking into GVCs has also been documented for product innovation in the case of European firms (Veugelers, Barbiero, and Blanga-Gubbay 2013) and on product scope and innovation for Turkish firms (Lo Turco and Maggioni 2015). More recently, Meyer (2020) finds that the more deeply a firm engages in GVC trade, the more likely it is to engage in innovation activities, including in product innovation. In particular, the author finds that Indian firms that are highly integrated into GVCs are 34 percent more likely to engage in product innovation due to higher knowledge spillovers.

In this paper, we make an important empirical contribution to the nascent literature on drivers of firm-level product upgrading in emerging economies. We examine the role of global value chains (GVCs) in facilitating firms' product upgrading, captured through increases in firm-level sales-weighted average product sophistication. Panel data on Indian manufacturing firms are collected for the period 2001–2015 from the Prowess database, and methodologies of System GMM and Propensity Score Matching (PSM) are deployed to empirically examine the impact of both linking into GVCs and the magnitude of participation on firm-level product sophistication. Previously, Eck and Huber (2016) have found that vertical backward FDI spillovers from downstream MNEs to upstream local Indian suppliers can boost supplier firm's sophistication. For Turkish manufacturing firms, Javorcik, Lo Turco, and Maggioni (2018) also find a positive correlation between the presence of foreign affiliates in the downstream sectors and the sophistication of new products. For Indian GVC firms, investment into digitally capabilities, industry concentration, and to some extent, research and development

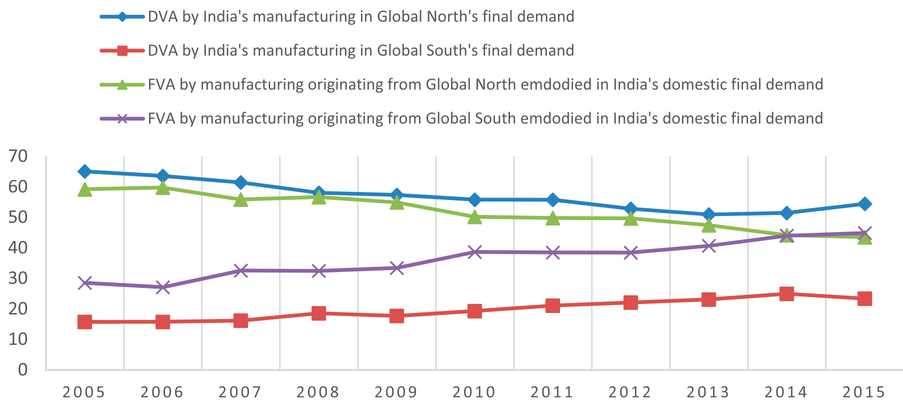

Figure 1. India's manufacturing GVC trade, by partner shares (%). Source: Author, constructed from OECD-TiVA database. Global South comprises of 22 developing countries in TiVA.

(R&D), has been found to facilitate firm sophistication, while age is found to have a negative impact (Banga 2022a).

The remainder of the paper is structured as follows. Section 2 presents emerging trends in India's GVC participation at the country-level, focusing on the changing geographies of India's GVC trade. Section 3 describes the data and construction of indicators and controls used in the study. Section 4 presents summary statistics and descriptive analysis. Section 5 outlines the econometric model and empirical strategy adopted in the study. Section 6 presents empirical results of the impact of linking into GVCs and increasing GVC embeddedness on firm-level product sophistication. Section 7 concludes the paper by discussing the results in context of other studies and arising policy implications.

2. India's changing geographies of GVC trade and export sophistication

India forms an interesting case-study to examine; despite its proximity to 'Factory Asia' (Baldwin 2008), India has low participation in global networks, especially amongst South Asian economies (Athukorala 2013). This has been attributed to the stagnant growth of its manufacturing sector, low ability to attract FDI in manufacturing, domestic-oriented markets and low R&D levels (Ray and Miglani 2018). Moreover, its existing GVC linkages are in low value-added manufacturing tasks, underscoring the need for Indian GVC firms to climb up the manufacturing export chain ladder.

An interesting macro-level trend in India's GVC trade is the gradual shift away from the Global North towards the Global South, mirroring the rise of 'polycentric trade' seen in other developing countries (Horner and Nadvi 2018). As show in Figure 1, the share of manufacturing foreign value-added (FVA) in India's domestic final demand originating from the Global North declined from 60% in 2005 to 43% in 2015, while that originating from Southern partners increased from 27% in 2005 to 45% in 2015. Similarly, the domestic value-added (DVA) by India's manufacturing in foreign final demand has declined by almost 10 percentage points for the case of Northern partners in the period 2005-2015, while increasing from 15% to 23% in the case of Southern partners.

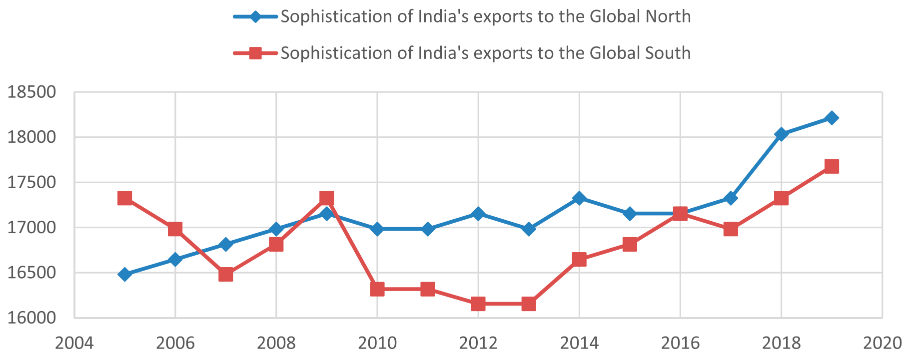

Figure 2. India's export sophistication, by partner. Source: Author, constructed from WITS, UNCOMTRADE, using Hausmann et al.'s (2007) product sophistication index.

Exporting to developed economies can increase a firm's sophistication level, albeit with diminishing returns (Baliamoune-Lutz 2019). A shift in India's GVC trade towards the Global South therefore raises concerns for India's overall export sophistication, especially since India's export basket to the Global South since 2010 has been consistently less sophisticated than its export basket to the Global North (Figure 2). However, this shift could create new opportunities for Indian firms to upgrade since South-South (SS) value chains are easier to enter and less tightly controlled (Tessmann 2018). In the case of East African firms, SS value chains offered higher opportunities for value-addition and skilled employment than North-South (NS) chains (Mohanty, Franssen, and Saha 2019). Unpacking the heterogeneity in GVC benefits across export destinations forms a critical area of future research but remains beyond the scope of this study, since information on the import/ export destination for Indian firms is not available publicly.

3. Data and construction of variables

To examine whether linking into GVCs can facilitate product upgrading in Indian firms, the study uses Prowess, a database of the financial performance of Indian companies, created by the Centre for Monitoring Indian Economy Pvt Ltd (CMIE) and extensively used in Economics and Business studies. For this study, only manufacturing firms in the period 2001–2015[1] are considered, and information is drawn on several firm-level variables including on sales, investment, capital, energy, materials, services, foreign equity, imports and exports. As part of data cleaning, observations with missing or negative value for sales as well as outlying observations are removed. On an average, a firm is present in the dataset for 11 years out of 15 years[2]. This cleaned panel contains around 69,768 firm-year observations. Of these, we are able to construct the firm-level product sophistication index for 56,129 observations used the methodology below.

3.1. *Firm-level product sophistication*

The firm-level product sophistication index is calculated used the approach outlined in Eck and Huber (2016) and Banga (2022a). In the first-step, the sophistication level of each manufacturing product k at the HS four-digit level is calculated using the $prody^k$ indicator (Hausmann, Hwang, and Rodrik 2007), which measures the income per capita associated with each product, weighted by a variant of Balassa's RCA. It is calculated using the following formula:

$$prody^k = \sum_c \underbrace{\left(\frac{X_c^k / X_c^w}{\sum_c \left(X_c^k / X_c^w \right)} \right) Y_c}_{\varphi_c^k},$$

where Y_c is the per capita income of country, X_c^k denotes country c's export volume of good k, and X_c^{w} is the sum of exports of country c. The weights φ_c^k add up to one for each good and the adjusted weight ensures "that country size does not distort the ranking of goods." (Hausmann, Hwang, and Rodrik 2007, 10). Data on GDP per capita (PPP) in constant US dollars (2011 USD) is collected from World Development Indicators and product-level export data is collected from the World Integrated Trade Solutions (WITS) data in UNCOMTRADE. Data is obtained from a consistent sample of 113 countries for which both data on export and GDP is consistently available for the period 2001–2015.

In the next step, a sales-weighted average sophistication level is constructed for each firm i in Prowess producing product $k = 1, \ldots K$ using the following formula;

$$PS_{it} = \sum_k \frac{Sales_{it}^k}{\sum_k^K Sales_{it}^k} prody^k,$$

where $Sales_{it}^k$ is the sales of product k by firm i at time t, and $\sum_{\mathrm{k}}^{\mathrm{K}} \mathrm{Sales}_{\mathrm{it}}^{\mathrm{k}}$ is the total sales of firm i across all products at time t. To classify and match products in Prowess with those in WITS, the study adopts the matching procedure as detailed in Banga (2022a). Around 80% of products are matched at the HS 4-digit level.

3.2. Measuring GVC participation

Following the standard practice in literature, we identify Indian GVC firms using a dummy variable which is $= 1$ if a firm is simultaneously importing intermediate goods and exporting intermediate or final goods at a given point of time, otherwise 0[3] (Baldwin and Yan 2014; Antràs 2020; Dovis and Zaki 2020; Urata and Baek 2020; Rigo 2021; Ehab and Zaki 2021; Banga 2022b). Some studies have attempted to capture the magnitude of firm-level GVC participation by distinguishing between ordinary trade and processing trade (see Upward, Wang, and Zheng 2013; Kee and Tang 2016; Lu et al. 2018). However, in the absence of such firm-level data on processing trade for various emerging economies, studies have adapted Hummels, Ishii, and Yi's (2001) vertical specialisation index at the firm level to measure the magnitude of GVC participation (see Banga 2022b; Reddy and Sasidharan 2021; Montalbano and Nenci 2020; Tucci 2005).[4]

The vertical specialisation index for firm i at time t is given by the following formula:

$$\mathrm{VS}_{1\mathrm{it}} = \frac{import\ of;\ raw\ materials,\ stores\ and\ spares,\ capital\ goods,\ services_{it}}{expenditure\ on;\ raw\ material,\ stores\ and\ spares,\ gross\ fixed\ assets,\ services._{it}} * \left(\frac{\mathrm{Exports_{it}}}{\mathrm{Sales_{it}}} \right)$$

Table 1. Construction of variables.

Variable	Construction
Deflated sales	Sales value deflated using 2-digit industry-specific Wholesale Price Index, collected from Office of Economic Advisor (OEA)
Deflated GVA	Nominal sales adjusted for change in inventory and purchase of finished goods to get nominal output. Then expenditure on raw materials and expenditure on stores and spares is subtracted form nominal output to get nominal GVA. Real GVA is obtained by deflating using 2-digit industry-specific WPI, same as sales.
Export intensity	(Total exports/ Total sales) ∗100
Size	Ln (Deflated Total assets), Ln (Deflated sales)
Age	Reporting year – Incorporation year
Foreign firm	Firms with more than 10% foreign ownership
Labour productivity	Deflated GVA/Total persons engaged
HHI	Sum of squares of the market shares of all firms operating in a particular industry
R&D intensity	Current account research and development expenditure, as a share in total sales
Operational TC	Index constructed using principal component analysis on royalty, technical-how how fee, license fee and foreign expenditure on capital goods.
Import content of exports	Import of raw materials, capital goods, stores and spares, services/exports) × 100

whereVS_{1it} refers to the imported intermediate inputs embodied in firm-level exports, normalised by material inputs. It combines the upstream and downstream linkages of a firm and increases as import and export shares rise. The upper bound of this index is 1, which is assigned to a firm when it uses only foreign inputs and sells all its output in the foreign market.

3.3. Construction of control variables

When empirically examining the impact of GVC participation on firm-level product sophistication, we control for several factors, such as foreign shares, R&D intensity, firm productivity, firm-level technological capability, product scope, firm age and size, and industry concentration (HHI). The construction of these variables is explained in Table 1 below.

To capture firm productivity, we use two alternative measures. First, we estimate labour productivity, measured as real gross value added (GVA) divided by total persons engaged. The GVA is deflated by 2-digit industry-specific wholesale price index (WPI), obtained from the Ministry of Commerce and Industry, Government of India. Since the data on total persons engaged is very patchy in Prowess, we use data from Annual Survey of Industries (ASI). The average industrial wage-rate is calculated by dividing total emoluments with total employees for each industry in ASI. The ASI industries are then matched to industries in Prowess using concordances. Wages and salaries reported by each firm in Prowess are subsequently divided by the corresponding average wage-rate to get firm-level labour input[5].

We also estimate firm-level total factor productivity (TFP) using the Levinsohn and Petrin (2003) approach, wherein firms' energy inputs are used as a proxy for unobserved productivity shocks. Studies that have previously adopted this approach to measure TFP for Indian manufacturing firms include Topalova and Khandelwal (2011) and Banga

(2022b). Nominal value-added is deflated using 3-digit industry level deflators, constructed from the WPI series. Real energy input is constructed as the sum of nominal expenses on power and fuel, deflated by the energy deflator obtained from the WPI series. Capital stock is constructed using the perpetual inventory method. While firm TFP is a better measure to capture efficiency of the firm, it comes at the cost of a significant loss of observations since we need at least three years of data for each firm. We therefore present results using the two alternative indicators for firm productivity.

4. Econometric model and empirical strategy

The baseline specification of the econometric model adopted to examine the impact of linking into GVCs on firm-level product sophistication is:

$$PS_{it} = \alpha_0 + \alpha_1 PS_{it-1} + \beta_1 GVCstatus_{it} + \beta_2 R\&D\ intensity_{it} + \ \beta_3 HHI_{jt} + \beta_4 X_{it} + a_i + a_j + a_t + e_{ijt} \tag{1}$$

For testing the impact of increasing magnitude of GVC participation on firm-level product sophistication, the sub-sample of GVC firms is taken, and the following econometric model is estimated:

$$PS_{it} = \alpha_0 + \alpha_1 PS\ _{it-1} + \beta_1 GVCembeddedness_{it} + \beta_2 R\&D\ intensity_{it} + \beta_3 HHI_{jt} + \beta_4 X_{it} + a_i + a_j + a_t + e_{ijt} \tag{2}$$

where PS_{it} describes the average product sophistication of firm *i* at time *t*, while PS_{it-1} is firm sophistication in the previous period, introduced in the model to capture persistency in product upgrading (Kočenda and Poghosyan 2018; Hidalgo et al. 2007). An increase in the average product sophistication level of the firm could be driven by the introduction of new and more sophisticated products or a shift towards already existing but more sophisticated products in the firm's product basket.

$GVCstatus_{it}$ is a dummy variable equal to 1 if a firm is participating in a GVC at time *t*, and otherwise zero, while $GVCembeddedness_{it}$ is the actual magnitude of participation of a GVC firm. $R\&Dintensity_{it}$ captures the internal efforts by firms to innovate, while industry concentration is controlled for through the Herfindalh index (HHI_{jt}). $\mathrm{X_{it}}$ refers to a set of control variables that includes firm characteristics such as age, size, foreign ownership, foreign shares, product scope (single product firms or multiple product firms) and firm productivity. Firm, industry and time fixed effects are captured by terms $\mathrm{a_i}$, $\mathrm{a_j}$, and $\mathrm{a_t}$, respectively.

The main econometric problem in estimating equations 1 and 2 is that of endogeneity arising due to simultaneous shocks in unobserved firm characteristics- such as unobserved productivity- that can affect both firm sophistication and GVC integration. There could also be reverse causality between PS and the GVC embeddedness; firms with higher PS might be in a better position to bear the sunk costs associated with international trade, finding it easier to embed more deeply into GVCs (Díaz-Mora and García López 2018). Other variables potentially endogenous to product sophistication include labour productivity, R&D intensity, technological capability, foreign shares and firm size.

To deal with the problem of endogeneity, the study deploys the System-GMM estimator, specifically designed for a dynamic dependent variable and 'small T large N panels' (Roodman 2009). In the absence of valid external instruments, the System GMM approach uses internal instruments to deal with endogenous variables (Roodman 2009). It simultaneously runs the econometric model in levels and differences, using lagged values of levels as instruments for the first differenced equation and lagged values of first differences as instruments for the levels equation. As per Monte Carlo simulations, GMM-type estimators outperform the instrumental-variable and fixed-effects estimator for determining drivers of product sophistication in a dynamic panel data setup, especially when the coefficient of the lagged dependent variable is close to 1 (Kočenda and Poghosyan 2018). Recent studies that have used the System GMM approach to examine export sophistication and productivity in the context of GVCs include Atasoy (2021), Banga (2022a, 2022b) and Pasquali, Krishnan, and Alford (2021).

Another econometric problem is the self-selection of more productive firms into GVCs, which could lead to biased results (Chor, Manova, and Yu 2014; Melitz 2003). Studies have previously used Propensity Score Matching (PSM)[6] to address this issue of self-selection in GVCs (Baldwin and Yan 2014; Benkovskis et al. 2020). Following Banga (2022b), we deploy a two-stage empirical strategy, which runs the System GMM estimator on a matched sample of GVC and non-GVC firms to address issues of both endogeneity and self-selection. Here, we consider linking into a GVC as the treatment variable. We first estimate the conditional probability of a firm to enter a GVC in our panel, using the logit model as specified in equation 3. The pscore specification of the model is guided by the a) inclusion of lagged variables, measured before entry to ensure exogeneity; b) balancing of all covariates in each year of the panel; c) inclusion of variables that are expected to affect both the treatment (GVC participation) and the main dependent variable (firm sophistication) (Caliendo and Kopeinig 2008); and d) exclusion of insignificant variables (Bryson, Dorsett, and Purdon 2002).

The probability of firm i entering a GVC at time t is modelled as;

$$Prob(GVCentry_{it} = 1) = \emptyset[\beta_1 Z_{it-1} + \beta_2 \gamma_{it} + a_j + a_t] + e_{it} \tag{3}$$

where the probability of entering a GVC is a function of lagged firm-specific attributes in Z, including firm TFP, R&D intensity, size, and foreign ownership as well as exogeneous current firm specific attributes (γ_{it}) such as age, and time and industry fixed effects (a_t) and (a_j), respectively.

The GVC entrants are then matched to non-GVC entrants with similar propensity scores, using Kernel matching. Matching is done for each year separately. Common support and Kernel density plots graphed for each year separately confirm the validity of the matching process (see appendix Figure A1 and Figure A2 for an example). Results of the 'pstest' in appendix Table A1 further confirm the success of matching; the pseudo R2 is found to be 0.102 for the matched samples and 0.007 for the unmatched sample, which is lower. After removing observations outside Common Support, we retain 63% of the matched sample.

System GMM regressions are run using equation 1 on both the matched and unmatched sample, using the 'xtabond2 'command by Roodman (2009), with two-step estimation and robust standard errors, clustered at the firm-level. The 'orthog' option is used to preserve sample size in our panel with gaps. Time dummies are included in all the models and the instrument set is collapsed when it exceeds the number of panels. The validity of results is further checked using the Arellano-Bond's autocorrelation test; a p-value greater than 0.05 indicates that there is no autocorrelation in the second order lag- AR (2)- at 5% level of significance. A p-value greater than 0.05 on the Hansen's J

Table 2. Summary statistics for Panel A (all firms).

Variable	Obs	Mean	Std. Dev.	Min	Max
Product sophistication	56129	27.73	9.68	0	100
Sales	56129	30.22	135.80	0.01	4773.07
Output	56129	28.71	131.29	0.01	4310.50
GVA	56129	13.82	71.45	0.00	2627.62
Operational TC	56129	0.60	7.07	0.00	427.92
Total persons engaged	55664	1344	6566	1	327125
Labour productivity	55664	1.75	8.28	0.07	878.60
TFP	16989	0.03	0.04	0.00	0.76
HHI	56129	0.19	0.21	0.014	1
GVC firms	56129	0.36	0.48	0	1
Only importer	56129	0.17	0.37	0	1
Only exporter	56129	0.10	0.31	0	1
Export intensity	30476	22.74	26.77	0.01	100
Foreign shares	55558	2.42	10.97	0.00	96.80
Foreign firm	55558	0.08	0.27	0	1
R&D intensity	56125	0.20	1.42	0.00	94.72
Multi-product firm	54329	0.54	0.5	0	1
Big firm	56129	0.48	0.50	0	1
Small firm	56129	0.20	0.40	0	1
Medium firm	56129	0.31	0.46	0	1

Source: Panel has been constructed from Prowess, for the period 2000/01- 2014/15
Notes: Sales and output variables are reported in Rs. Million and have been deflated using 2 digit WPI indices. Prod. sophistication has been normalised to range between 0 and 100. Summary statistics on export intensity, R&D intensity and foreign shares are presented only for firms that are exporting, conducting R&D and foreign firms. Labour productivity estimates have been multiplied by 100 for scale.

-test of over-identifying restrictions indicates that the null hypothesis of exogeneity of the instrument set cannot be rejected.

5. Summary statistics and descriptive analysis

The empirical results reported in this chapter draw on two firm-level panels, constructed from Prowess- Panel A (All Firms) and Panel B (GVC Firms). The summary statistics for Panel A are given in Table 2. The sales-weighted firm-level sophistication index has been normalised and ranges from 0 to 100, with the average sophistication index being roughly 27. To validate the firm-level sophistication index calculated using $prody^k$, product sophistication is also calculated using seven alternate measurements techniques (appendix Table A2). The Spearman rank correlation matrix reveals a high correlation- greater than 60%- between $prody^k$ and the other indicators (appendix Table A3), confirming the validity of the average firm -level sophistication indicator, constructed using $prody^k$.[7]

Across industries, we find that pharmaceuticals, machinery and equipment, computer and electronics, motor vehicles, transport equipment, chemicals etc. have higher product sophistication, on an average, than industries of food products, beverages, leather, textiles etc (Figure 3). A closer look at product-level (HS 4-digit level) disaggregated data shows that products of 'petroleum gasses and other gaseous hydrocarbons' and 'nucleic acids and other salts' feature in the topmost sophisticated products (appendix Table A4). Other highly sophisticated products include cermets and its articles, sulphonamides, self-adhesive plates, photographic equipment, machinery for rubber and plastic products and halogenated derivatives of hydrocarbons. The least sophisticated products

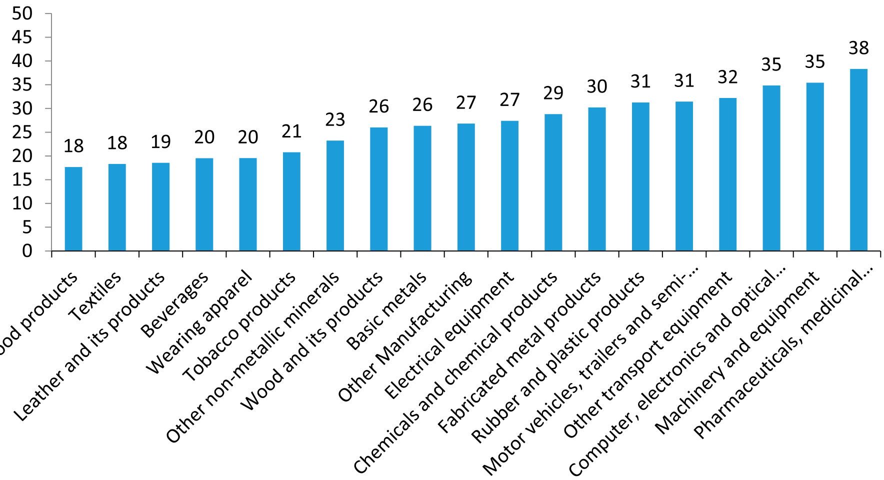

Figure 3. Product- Sophistication index across manufacturing industries. Source: Author, Panel A (2001–2015). Note: For calculating product-specific sophistication level, prody^k is used. Average firm-level product sophistication has been normalised for easier comparison across industries.

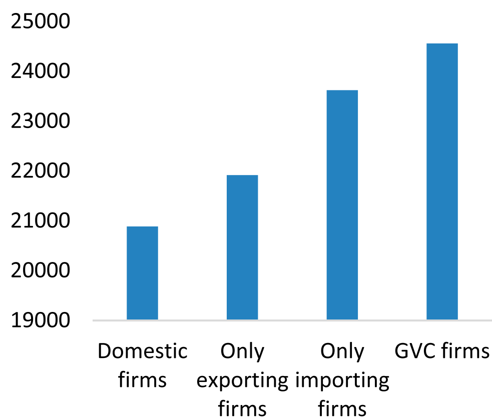

Figure 4. Average firm level PS (in $).

include uranium, tin and tungsten ores as well as cotton and jute fibres. These findings are in line with Eck and Huber (2016), who use the alternative SITC nomenclature instead of HS nomenclature to classify products.

Of the 56,129 firm- year observations in Panel A, roughly 36% are GVC firms; 10% are only exporting; 17% are only importing; and 37% of firms do not participate in international trade. Examining average product sophistication across types of traders (Figure 4), we find that GVC firms have the highest sophistication level, followed by only- importing firms, only exporting firms and lastly, domestic firms. Tracing the sales-weighted firm-level product sophistication overtime (Figure 5) reveals that product sophistication in Indian GVC firms has remained consistently higher than that in non-GVC firms but the difference in product sophistication between GVC and non-GVC firms has increased from 1.78 percentage points in 2001 to 4.54 percentage points in 2015.

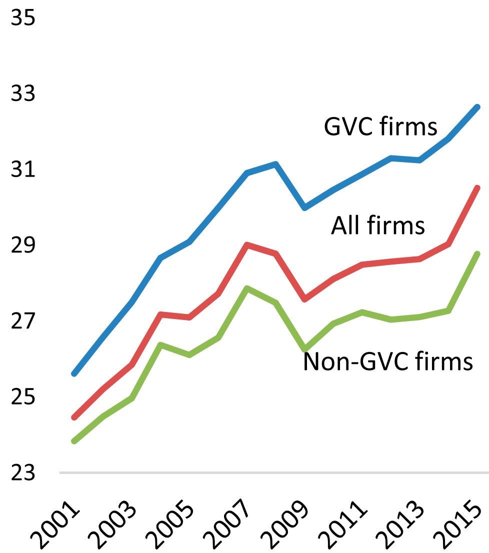

Figure 5. Mean PS index, across firms. Source: Author, constructed from Panel A, Prowess.

Around 54% of the firms in Panel A are identified as multi-product firms[8] and around 8% of the sample is foreign owned. From Figure 6, it is further observed that only 4.2% of non-GVC firms are foreign owned, while 14.3% of GVC firms are foreign owned. Around 58% of the GVC firms produce multiple products as compared to 47% of non-GVC firms, and around 70% of GVC firms employ more than 250 employees (large – sized firms). The summary statistics of Panel B (GVC firms only) are given in appendix Table A5.

6. Empirical results

6.1. Impact of GVC participation on firm sophistication, unmatched sample

Table 3 presents results for the impact of linking into GVCs on firm-level product sophistication. Seven alternate model specifications are presented, across which the coefficient on the PS_{it-1} is positive and significant, ranging between 0.61 and 0.72. This implies that there is significant persistency in PS, confirming the validity of using the GMM approach.

A positive and significant coefficient is observed on R&D intensity and HHI index, while age is found to have a significant and negative impact. We find no significant impact of firm productivity- both labour productivity and total factor productivity- and foreign ownership on product sophistication. Coming to the main variable of interest – the GVC firm dummy- it is observed that the coefficient is positive and significant across all six models, implying that Indian manufacturing firms that are participating in GVCs have higher product sophistication, on average and ceteris paribus, than non-GVC firms. The p value on the AR(2) and Hansen's test statistic is greater than 0.10, indicating the validity of the results.

The significant and positive impact of the GVC participation dummy on firm sophistication is further robust to the use of one-step GMM estimation which checks against

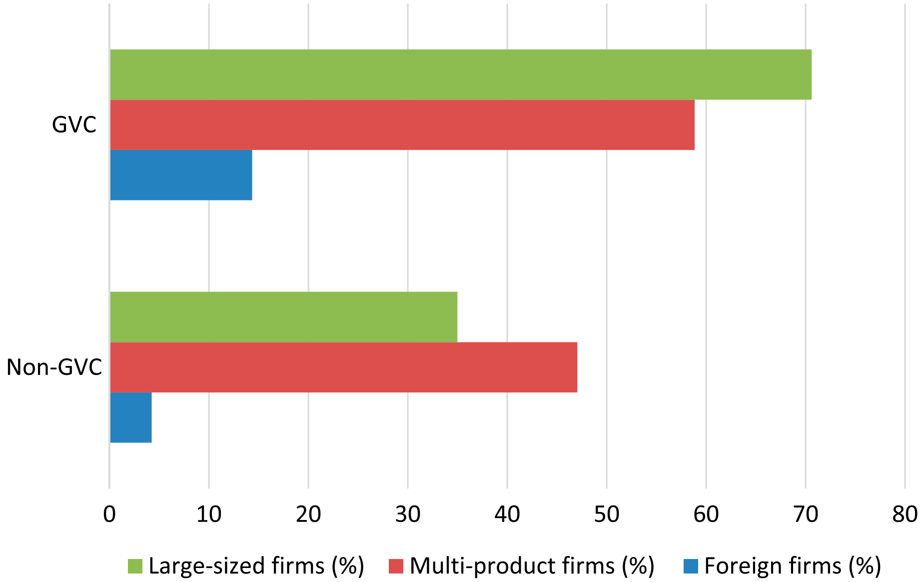

Figure 6. Distribution of firms, across GVC and non-GVC status. Source: Panel A (2001–2015).

any downward bias in two-step GMM estimations (appendix Table A6); an interaction term between GVC and foreign share variable (appendix Table A6); an alternate measurement of labour productivity, calculated as output/ total persons engaged (appendix Table A7); and a different lag specification for endogenous variables (appendix Table A7). We also check against attrition bias caused due to GVC firms having a higher probability of survival in the market than one-way traders and domestic firms. Models 3-5 in appendix Table A7 confirm the robustness of results using a balanced panel[9] between 2001 and 2015, and Model 6 presents results for a small sub-sample in the period 2009-2015. Lastly, we check sensitivity of results to the measure of product sophistication. In appendix Table A8, the sales-weighted average firm-level product-sophistication is calculated using prody_mean2, which takes the average of $prody^k$ over time (in the period 2001–2015). The coefficient on the GVC dummy remains positive and significant and comparable to the results using $prody^k$.

6.2. *Impact of GVC participation on firm sophistication, matched sample*

Table 4 presents the PSM- System GMM results on the matched panel of GVC and non-GVC firms to address both the issues of self-selection and endogeneity. Six alternate model specifications are presented, across which the coefficient on the PS_{it-1} is positive and significant. The *p* value on AR (2) and Hansen's test statistic is above 0.10.

Even after controlling for self-selection of firms into GVCs, we find that linking into GVCs increases average firm-level product sophistication. Firms that are younger, more innovative, and those in more concentrated industries, have higher product sophistication levels, on average, than their counterparts. Again, foreign ownership, the magnitude of foreign shares and total factor productivity are not found to be significant drivers of firm sophistication in India. From appendix Table A9, we note that these results are

Table 3. System GMM results, unmatched sample, Dependent variable: Log ($\mathrm{PS_{it}}$).

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
L. Log (PS)	0.606***	0.63***	0.721***	0.63***	0.780***	0.756***
	(0.07)	(0.08)	(0.05)	(0.09)	(0.0588)	(0.0687)
HHI	0.0537***	0.0645***	0.0548***	0.064***	0.0316***	0.0498***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.0119)	(0.0150)
Log (R&D intensity)	0.0042***	0.0041***	0.0028***	0.004***	0.00155*	0.00278***
	0.0010)	(0.0013)	(0.0010)	(0.001)	(0.000837)	(0.000988)
GVC firm	0.0173*	0.0179*	0.0231**	0.019**	0.0306**	0.0301**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.0130)	(0.0137)
Log (age)		−0.00588	−0.0109**	−0.0080		−0.0163***
		(0.0058)	(0.0049)	(0.0058)		(0.00578)
MP firm		−0.0113*	−0.00529	−0.0077		0.00264
		(0.0064)	(0.0049)	(0.0055)		(0.00509)
Foreign shares		−0.00035	−0.00021	−0.0003		
		(0.0003)	(0.0003)	(0.0003)		
Royalty/sales				0.0066*		
				(0.0040)		
Log (labour prod.)	0.0246*	0.0181	−0.00459	0.0115		
	(0.0139)	(0.0171)	(0.0084)	(0.0134)		
Log (TFP)					0.0389	0.00406
					(0.0422)	(0.0476)
L. Log (TFP)					−0.0259	−0.00239
					(0.0278)	(0.0315)
Log (sales)			−0.00013			
			(0.0050)			
TC control	Yes	Yes	Yes	No	no	yes
Time FE	yes	yes	yes	yes	yes	yes
AR (2)	0.15	0.147	0.149	0.135	0.58	0.519
Hansen *p*-value	0.168	0.12	0.059	0.34	0.159	0.421
Observations	45,599	43,554	43,554	43,554	12,839	12,353
Number of firms	6,896	6,526	6,526	6,526	2,597	2,504
Instruments	36	33	36	30	29	31

Note: Data used is from panel A (All firms) for the period 2001–2015. Product sophistication (PS) is measured using prody^k. MP firm refers to multi-product firm. The natural log of sales and employment is a proxy for firm size. Time fixed effects and constants are included in all models, but coefficients are not reported. AR(1) = 0 across all models. Standard errors are two-step robust, clustered on firms and reported in parentheses. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$. TC refers to a control for technological capability of the firm; an index constructed from principal component analysis, which captures technical know-how fee, fee on royalties and licences.

robust to one-step GMM estimations (model 1), changes in lag structure (Models 2), and the use of a truncated sub-sample, which includes only those Indian manufacturing firms that employ more than 10 workers and have atleast Rs. one million of sales (Models 3 and 4).

6.3. *Impact of GVC embeddedness on firm sophistication*

System GMM results for the impact of increasing depth of GVC participation on PS are reported in Table 5. The magnitude of GVC participation is proxied by a firm-level measure of vertical specialisation VS1, which measures the imported intermediates embodied in firm-level exports, wherein intermediate imports include raw materials, stores and spares, capital goods and services.

Even in the sub-sample of GVC firms, age is found to be negatively associated with firm sophistication. There is some evidence of a positive impact of firm size on sophistication, and a positive and significant coefficient is also found for R&D intensity. On the

Table 4. System GMM results, matched sample, Dependent variable: Log (PS_{it}).

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
L.log PS	0.732***	0.730***	0.744***	0.691***	0.618***	0.741***
	(0.0627)	(0.0627)	(0.0601)	(0.0627)	(0.0707)	(0.0621)
Log (R&D intensity)	0.00201***	0.00197***	0.002***	0.00170***	0.000462	0.00207***
	(0.000518)	(0.000519)	(0.00052)	(0.000603)	(0.000472)	(0.000557)
GVC firm	0.0313**	0.0290*	0.0251*	0.0380***	0.0270**	0.0278*
	(0.0152)	(0.0153)	(0.0151)	(0.0145)	(0.0137)	(0.0151)
Log (TFP)	0.00310	0.00515	0.00581	0.00274	−0.00138	0.00385
	(0.00755)	(0.00765)	(0.00764)	(0.00692)	(0.00669)	(0.00760)
Log (age)	−0.0211***	−0.0200***	−0.019***	−0.0212***	−0.0154***	−0.0173***
	(0.00557)	(0.00547)	(0.00570)	(0.00597)	(0.00502)	(0.00549)
HHI	0.0413***	0.0485***	0.0476***	0.0598***	0.101***	0.0500***
	(0.0112)	(0.0121)	(0.0122)	(0.0134)	(0.0197)	(0.0128)
Multi-prod firm		0.000636	0.00176	−0.00690	0.00335	0.00167
		(0.00556)	(0.00543)	(0.00670)	(0.00503)	(0.00544)
Foreign firm			−0.0182	−0.0287	−0.0268	
			(0.0260)	(0.0273)	(0.0271)	
Log (Real sales)				0.00879	0.00502	
				(0.00584)	(0.00507)	
Foreign Shares						−0.000744
						(0.000490)
Industry FE	no	no	no	no	yes	no
Time FE	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
Observations	12,840	12,446	12,446	12,446	12,446	12,446
Number of firms	2,597	2,527	2,527	2,527	2,527	2,527
AR(2)	0.45	0.54	0.528	0.577	0.592	0.524
Hansen *p* val	0.23	0.375	0.465	0.215	0.173	0.535
No. of Instruments	33	34	40	46	67	40

other hand, no significant product sophistication premium is found for foreign-owned GVC firms compared to domestic-owned GVC firms. Turning to the main variable of interest, log VS1, it is observed that the coefficient on vertical specialisation is positive and significant across all models. This holds true even after controlling for participation of firms in high-technology sectors in Model 6. The positive impact of GVC embeddedness on firm sophistication is robust to changes in the measurement and choice of vertical specialisation measure. These results are robust to the use of alternative methods for measuring vertical specialisation- VS2 which excludes services from intermediates inputs and VS3, which excludes capital goods (see appendix Table A10). The results are also robust to the measurement of VS as the ratio of imported intermediates to total exports (appendix Table A11).

7. Discussion of results and future work

Using a sample of Indian manufacturing firms in the period 2001–2015 and methodologies of System GMM and Propensity Score Matching, we find that linking into GVCs can boost the average product sophistication level in Indian firms by roughly 2%, on average and ceteris paribus. The magnitude of participation also matters; increasing GVC embeddedness, captured through vertical specialisation, significantly boosts product sophistication in Indian GVC firms. Perhaps, as a firm gets more GVC-oriented, the positive 'learning by importing and exporting' effect gets stronger. Another potential reason could be that Indian manufacturing firms integrated into GVCs are much more likely to

Table 5. System GMM results; impact of GVC embeddedness on Log(PS_{it-1}).

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Log (PS_{it-1})	0.808***	0.802***	0.798***	0.790***	0.793***	0.803***
	(0.0429)	(0.0430)	(0.0432)	(0.0471)	(0.0457)	(0.0478)
Log (PS_{it-2})	0.0777*	0.0795*	0.0830**	0.0851**	0.0817*	0.046
	(0.0404)	(0.0406)	(0.0400)	(0.0421)	(0.0440)	(0.0431)
Log (VS1)	0.00767**	0.00613*	0.00695*	0.00657*	0.00621*	0.0064*
	(0.00366)	(0.0037)	(0.00375)	(0.00360)	(0.00377)	(0.0035)
Log (age)	−0.0104*	−0.011**	−0.0113*	−0.014**	−0.00899*	−0.00664
	(0.00581)	(0.0058)	(0.00582)	(0.00564)	(0.00544)	(0.0049)
Log (employment)	0.00965*	0.00896*	0.00993**	0.00842	0.00597	0.0032
	(0.00498)	(0.0050)	(0.00501)	(0.00513)	(0.00518)	(0.0051)
Foreign firm		0.0209				
		(0.0168)				
Foreign shares			0.00020	0.00018	0.00011	0.00021
			(0.00019)	(0.00019)	(0.00018)	(0.0001)
Log (R&D intensity)				0.00131*	0.00144*	0.00042
				(0.00069)	(0.00075)	(0.0005)
HHI					0.00718	0.01568**
					(0.00647)	(0.0077)
Multi-product firm					−0.000647	0.0043
					(0.00421)	(0.0041)
Log lLabour prod.)					0.00597	0.00972
					(0.00872)	(0.00843)
High-tech sector						0.044***
						(0.0089)
Time FE	yes	yes	yes	yes	yes	Yes
Observations	11,670	11,611	11,611	11,611	11,259	11,259
Number of firms	1,980	1,961	1,961	1,961	1,899	1,899
Instruments	35	38	38	42	44	50
AR (2)	0.436	0.470	0.526	0.593	0.558	0.186
Hansen's p-val	0.166	0.08	0.24	0.06	0.07	0.062

conduct changes in their product composition (Meyer 2020). For the case of Chinese equipment manufacturing, Li et al. (2020) also finds a significant and positive impact of GVC embeddedness on export technical complexity of China's equipment products. Findings of our study have important policy implications- designing policies in developing countries to facilitate GVC integration can enable product upgrading, leading to economic development and growth. We find that R&D intensity has a positive and significant impact in both panels; complementary investments need to be made in firm-level internal innovative capabilities to maximise gains from linking into, and participating within, GVCs.

As in Eck and Huber (2016), age is found to have a negative impact on firm sophistication in India, both in the all firm-panel and in the GVC firm-panel. While older Indian firms are more likely to hold greater market power and the ability to innovate, it is the younger firms who have more incentives to innovate and remain competitive. The survival and growth of younger firms may depend more heavily on product innovation and manufacturing of more sophisticated goods. In line with previous firm-level studies (Eck and Huber 2016; Banga 2022a), we find no significant impact of foreign shares or foreign acquisition on firm sophistication While some studies have documented a positive relationship between FDI and export sophistication at the country-level (Harding and Javorcik 2012; Wang and Wei 2010), the effect of FDI on product sophistication depends on ownership structure and the sector invested (Xu and Jiangyong 2009).

Foreign firms in India could be pursuing cost-savings strategies, potentially investing in less-sophisticated low-cost goods.

We find a positive impact of industry concentration; a 1 unit rise in the HHI index increases firm's product sophistication level by 5%, on average and ceteris paribus. Industries which are more concentrated generate larger profits for firms, which may be getting re-invested into creation of more sophisticated product lines, as also found in Banga (2022a). Goldberg et al. (2010b) note that product churning in India is lower than in other countries, probably due to industrial licensing and rigid labour market regulations, and it occurs more through adding of products rather than dropping. However, there is not enough evidence of product sophistication significantly differing between single and multi-product firms in our study.

A caveat of our analysis is that Prowess does not report firm-level information on export destinations. As a result, we cannot account for heterogeneity in product sophistication gains across export destinations, which could be important, as discussed in Section 2. Future studies could attempt to examine how product sophistication gains from linking into GVCs differ across export destinations.

Notes

1. The choice of the time period is guiding by a range of factors. Our study period begins from the year 2001 since Prowess started publishing information on foreign ownership from 2001 onwards. The information on firm-level total persons employed is patchy in Prowess and we therefore use wage data from the Annual Survey of Industries (ASI) to construct firm-level labour. This data is only available in ASI till 2017. We further restrict the time series to 2015 because of other shocks to the Indian economy in subsequent years, such as the demonetisation in 2016.
2. For each year in the panel, information is available, on average, for 4650 firms, except for the year 2015, for which information was available for 2502 firms at the time of data collection.
3. Prowess reports on total exports of the firm but does not distinguish between intermediate and final exports.
4. A drawback of this approach using the Prowess dataset is that we cannot account for re-imports at the firm level.
5. A 10% wage-premium is added on the average wage-rate for foreign firms, following Goldar, Banga, and Renganathan (2004).
6. Introduced in the pioneering work of Rosenbaum and Rubin (1983).
7. Products that score high on $prody^k$ sophistication indicator also have high value (greater than 1) on the product complexity indicator – see Hidalgo and Hausmann (2009).
8. In our 2001–2015 panel, roughly 46% of the Indian manufacturing firms (for which product sophistication is calculated), are classified as single-product firms. This is lower than the share of single-product firms (approx. 53%) in studies of Goldberg et al. (2010b) and De Loecker et al. (2016), which use data from before 2004. This difference could be due to the different time periods considered, as well differences in the level and type of classification followed for standardisation of products from Prowess across studies.
9. The Phillips-Perron test on the balanced panel of 2001–2015 shows that firm-level product sophistication is stationary.

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Data availability statement

Data used in the study is propriety. It can be shared upon reasonable request and permission from third-party.

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Appendix

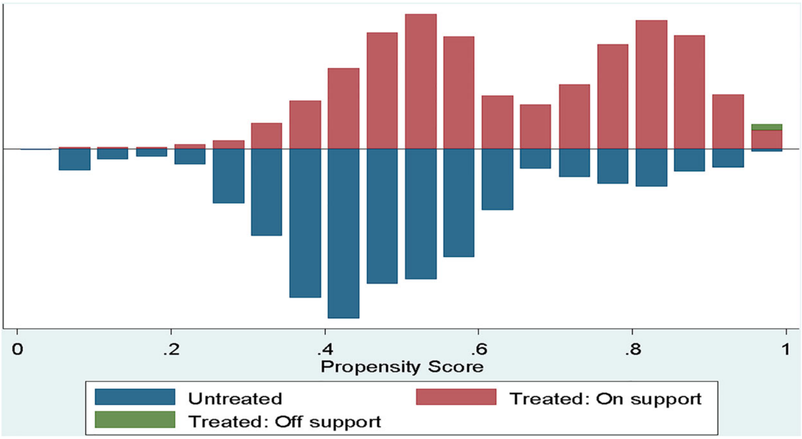

Figure A1. Graphing common support for treated and control groups, 2013.

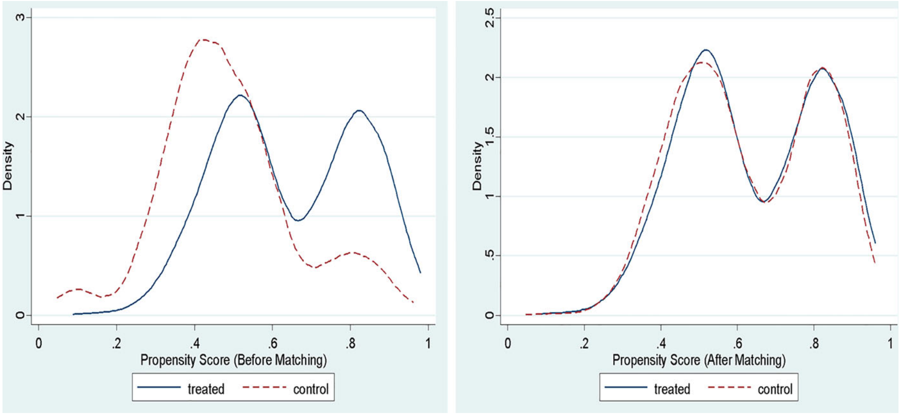

Figure A2. Kernel Density plots, *p*-scores before (left) and after (right) matching, 2013.

Table A1. Pstest results.

Sample	Ps R2	LR chi2	p > chi2	Mean Bias	Med Bias	B	R	% Var
Unmatched	0.102	2916.8	0	35.6	32.8	78.3*	1.84	75
Matched	0.007	8.48	0.292	5.7	4.8	19.3	0.95	25

Table A2. Construction of sophistication indicators.

Indicator type	Indicator	Avg. Export	Avg. GDP	Formula
Hausmann's PRODY indicator	$prody^k$	NO	NO	$\sum_c \frac{X_{ct}^k/X_{ct}^{\bullet}}{\sum_c (X_{ct}^k/X_{ct}^{\bullet})} Y_{ct}$
Variant of PRODY	Prody_mtrd	YES	NO	$\sum_c \frac{\overline{X}_c^k/\overline{X}_c^{\bullet}}{\sum_c (\overline{X}_c^k/\overline{X}_c^{\bullet})} Y_{ct}$
Variant of PRODY	Prody_mgdp	NO	YES	$\sum_c \frac{X_{ct}^k/X_{ct}^{\bullet}}{\sum_c (X_{ct}^k/X_{ct}^{\bullet})} \overline{Y}_c$
Variant of PRODY	Prody_Mean1	YES	YES	$\sum_c \frac{\overline{X}_c^k/\overline{X}_c^{\bullet}}{\sum_c (\overline{X}_c^k/\overline{X}_c^{\bullet})} \overline{Y}_c$
Variant of PRODY	Prody_Mean2	NO	NO	$\overline{prody^k}$ i.e. average of $prody^k$ over time.
Lall's soph indicator	$Lall^k$	NO	NO	$100 \cdot \left(\frac{SI_t^k - \min(SI_t^{k\in K})}{\max(SI_t^{k\in K}) - \min(SI_t^{k\in K})} \right)$ with $SI_t^k = \sum_{g=1}^{G=10} \left(\overline{Y_{gt}} \cdot \frac{X_{gt}^k}{X_{\bullet t}^k} \right)$
Michaley's soph. indicator	$\mathrm{Mic1}^k$	NO	NO	$\sum_c Y_{ct} \left(\frac{X_{ct}^k}{X_{\bullet t}^k} \right)$
Michaley's soph. indicator	$\mathrm{Mic2}^k$	YES	YES	$\widehat{\beta^k}$, taken from $\frac{\overline{X_c^k}}{X_{\bullet}^k} = \alpha + \beta^k \overline{Y_c} + \epsilon_c^k, \quad \forall k$

Source: Adapted from Huber (2017)

Note: Y represents GDP per capita, X_{ct}^k represents exports of country c in product k at time t, X_{*t}^k refers to exports of the world in product k at time t. Y_{ct} refers to GDP of country c at time t.

Table A3. Spearman rank correlation test between sophistication indices.

Indicators	$prody^k$	MIC2	MIC1	Lall	Prody_mtrd	Prody_mean1
MIC2	0.7288	1				
	(0)					
MIC1	0.7413	0.9585	1			
	(0)	(0)				
Lall	0.6604	0.9058	0.9338	1		
	(0)	(0)	(0)			
Prody_mtrd	0.963	0.7387	0.7295	0.6429	1	
	(0)	(0)	(0)	(0)		
Prody_mean1	0.9487	0.7619	0.755	0.6956	0.9695	1
	(0)	(0)	(0)	(0)	(0)	
Prody_mgdps	0.9732	0.736	0.7524	0.7013	0.9219	0.9572
	(0)	(0)	(0)	(0)	(0)	(0)
Prody_mean2	0.9524	0.7625	0.7556	0.6965	0.9653	0.995
	(0)	(0)	(0)	(0)	(0)	(0)

Notes: H0: correlation coefficient is zero. *P*-val indicated in brackets. *P*val $=$ 0 implies H0 can be rejected.

Table A4. Top and bottom sophisticated products (HS four-digit level) in 2014–2015.

HS code	PRODUCTS WITH HIGH SOPHISTICATION
8113	Cermets and articles thereof
7216	Petroleum gases and other gaseous hydrocarbons.
2935	Sulphonamides.
2934	Nucleic acids and their salts; other heterocyclic compounds.
3919	Self-adhesive plates, sheets, film, foil, tape, strip of plastics.
8477	Machinery for working rubber or plastics or their products
9010	Apparatus and equipment for photographic (including cinematographic) laboratories, apparatus for the projection or drawing of circuit patterns.
2903	Halogenated derivatives of hydrocarbons
HS code	**PRODUCTS WITH LOW SOPHISTICATION**
9050	Uranium or thorium ores and concentrates.
5203	Tin ores and concentrates.
2615	Cotton, carded or combed.
2611	Niobium, tantalum, vanadium or zirconium ores and concentrates.
5303	Tungsten ores and concentrates.
2401	Jute and other textile fibres, raw or processed but not spun
2614	Unmanufactured tobacco; tobacco refuse.
1801	Titanium ores and concentrates.

Table A5. Summary statistics, GVC firms panel, 2001–2015.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Sales	22274	7280.135	27985.89	1.7	591992
Export intensity	22274	28.60955	27.83	1.01	100
Product sophistication	19488	36.68	11.22	0.00	100
Foreign shares	22062	4.68	15.2383	0	96.8
Multiproduct firm	20496	0.588	0.492	0	1
Labour productivity	22166	1.2	2.00	0.1	120
Number of persons	22166	2523	10483	1	504601
HHI	22274	0.196	0.210	0.014	1

Source: Author, from Prowess.

Table A6. One-step GMM and adding interactions; log(PS).

Variables	Model 1 One-step	Model 2 One-step	Model 3 One-step	Model 4 Interaction	Model 5 Interaction
L. log(PS)	0.563***	0.564***	0.555***	0.565***	0.725***
	(0.0965)	(0.0960)	(0.0993)	(0.0958)	(0.0469)
HHI	0.0688***	0.0661***	0.0732***	0.0659***	0.0544***
	(0.0136)	(0.0133)	(0.0157)	(0.0132)	(0.0119)
Log (R&D intensity)	0.00245*	0.00543***	0.00555***	0.00540***	0.00271***
	(0.00140)	(0.00172)	(0.00185)	(0.00171)	(0.00100)
Log (sales)	−0.00571	−0.00864		−0.00872	0.000101
	(0.00586)	(0.00621)		(0.00623)	(0.00495)
Foreign shares (FS)	−0.000168	−0.000178		−0.000359	−0.000263
	(0.000277)	(0.000317)		(0.000556)	(0.000482)
Operational TC	0.000100	7.77e-05	−6.84e-05	7.68e-05	−5.77e-05
	(0.000240)	(0.000217)	(0.000230)	(0.000216)	(0.000188)
GVC	0.0214**	0.0281***	0.0242**	0.0281***	0.0226**
	(0.0103)	(0.00988)	(0.00984)	(0.0100)	(0.00920)
GVC∗FS				0.000330	0.000145
				(0.000540)	(0.000487)
Log (age)	−0.00266	−0.00713	−0.00398	−0.00729	−0.0112**
	(0.00627)	(0.00555)	(0.00694)	(0.00551)	(0.00482)
Log (Labour prod.)	0.0148	0.0170	0.0232	0.0166	−0.00547
	(0.0134)	(0.0138)	(0.0164)	(0.0136)	(0.00828)
Multi-product firm	−0.00829	−0.00832	−0.0119*	−0.00834	−0.00511
	(0.00587)	(0.00570)	(0.00616)	(0.00569)	(0.00492)
Log (employment)			−0.00596		
			(0.00552)		
Foreign firm			−0.0134		
			(0.0234)		
Standard errors	One step robust	One step robust	One step robust	One-step robust	Two step robust
AR2	0.11	0.11	0.11	0.120	0.148
Hansen	0.11	0.059	0.08	0.10	0.10
Time Fixed effects	yes	yes	yes	Yes	yes
Observations	43,554	43,554	43,554	43,554	43,554
Number of firms	6,526	6,526	6,526	6,526	6,526
Instrument count	31	36	36	39	39

Table A7. Robustness to measurement, lag specification and attrition; log(PS).

	Model1	Model 2	Model 3	Model 4 Balanced 2001–2015	Model 5	Model 6
	With LP calculated differently	With different lags	Balanced panel	Adding foreign ownership and size	Adding labour productivity	Balanced 2009-2015
L. log (PS)	0.718***	0.701***	0.605***	0.568***	0.560***	0.641***
	(0.0480)	(0.0541)	(0.0573)	(0.0624)	(0.0616)	(0.0814)
HHI	0.0527***	0.0624***	0.0531***	0.0589***	0.0613***	0.0323*
	(0.0131)	(0.0144)	(0.0151)	(0.0174)	(0.0172)	(0.0183)
Log (R&D intensity)	0.0025**	0.0027***	0.0029***	0.0030***	0.0030***	−0.000916
	(0.00102)	(0.000976)	(0.000772)	(0.000990)		(0.00175)
GVC firm	0.0232**	0.0244*	0.0405**	0.0390**	0.0377**	0.0500**
	(0.00900)	(0.0143)	(0.0204)	(0.0172)	(0.0168)	(0.0236)
Operational TC	−0.000117	−0.000262	−0.000177	−0.000151	−0.000140	4.25e-05
	(0.00020)	(0.000314)	(0.000164)	(0.000152)	(0.000154)	(0.000237)
Log (labour prod.)	−0.00546	−0.00152	0.0127	0.00318	0.00914	0.00586
	(0.00607)	(0.00974)	(0.0181)	(0.0148)	(0.00934)	(0.00456)
Log (age)	−0.0117**	−0.0121**	−0.0154*	−0.0199*	−0.0184*	0.00292
	(0.00503)	(0.00519)	(0.00932)	(0.0107)	(0.0102)	(0.0101)
Foreign firm	0.00396	−0.00233		−0.0153	−0.0189	−0.0369
	(0.0195)	(0.0228)		(0.0232)	(0.0218)	(0.0375)
MP firm	−0.00679	−0.00813	−0.0140*	−0.0211**	−0.0228**	−0.0183**
	(0.00504)	(0.00519)	(0.00825)	(0.00884)	(0.00931)	(0.00900)
Log (sales)	0.00105	0.00275				
	(0.00424)	(0.00491)				
Big firm				0.0352	0.0317	
				(0.0330)	(0.0317)	
Medium firm				0.00201	0.00141	
				(0.0268)	(0.0262)	
Observations	43,620	43,554	14,014	13,974	13,977	9,013
No. of firms	6,533	6,526	1,050	1,047	1,047	1,579
Instruments	36	36	26	39	39	25
Ar(2)	0.136	0.149	0.938	0.92	0.91	0.08
Hansen	0.126	0.359	0.14	0.11	0.19	0.06

Note: Constants and year dummies not reported. Time fixed effects are included in all models. Standard errors are two step robust, clustered on firms, for all models. AR(1) 0 for all models.

Table A8. Robustness to using a different dependent variable; log(prody_mean2).

Variables	Model 1	Model 2	Model 3	Model 4
L.log(prody_mean2)	0.476***	0.667***	0.674***	0.609***
	(0.171)	(0.115)	(0.113)	(0.174)
HHI	0.0637***	0.0558**	0.0550**	0.0658**
	(0.0208)	(0.0221)	(0.0217)	(0.0278)
Log (R&D intensity)	0.00542***	0.00388**	0.00374**	0.00421
	(0.00204)	(0.00182)	(0.00176)	(0.00260)
Log (sales)		−0.00418	−0.00391	
		(0.00488)	(0.00487)	
Foreign firm		−0.00921		
		(0.0163)		
Operational TC		−9.31e-05	−9.83e-05	−0.000193
		(0.000201)	(0.000202)	(0.000213)
GVC	0.0128*	0.0140**	0.0140**	0.0126*
	(0.00709)	(0.00699)	(0.00693)	(0.00702)
Log (age)		−0.00401	−0.00395	−0.00393
		(0.00569)	(0.00567)	(0.00573)
Log (labour prod.)	0.0394*	0.0111	0.0107	0.0187
	(0.0207)	(0.00859)	(0.00840)	(0.0129)
Multi-product firm		−0.00869	−0.00840	−0.0141*
		(0.00640)	(0.00631)	(0.00783)
Foreign shares			−0.000146	−0.000194
			(0.000214)	(0.000236)
Log (employment)				−1.83e-05
				(0.00564)
Time FE	Yes	yes	yes	yes
Standard errors	two-step robust	two-step robust	two-step robust	two-step robust
Number of instruments	28	36	36	42
AR(1)	0.029	0.044	0.03	0.05
AR(2)	0.458	0.467	0.462	0.493
Hansen *p*- val	0.155	0.16	0.356	0.242
Lags	2 and 3	2 and 3	2 and 3	2 and 4
Observations	45,599	43,554	43,554	43,554
Firms	6,896	6526	6526	6526

Note: Constants and year dummies are included but not reported

Table A9. PSM-GMM results, matched panel, robustness checks.

Variables	Model 1	Model 2	Model 3	Model 4
L.log (PS)	0.737***	0.709***	0.680***	0.737***
	(0.0753)	(0.0690)	(0.0653)	(0.0667)
Log (R&D intensity)	0.00165**	0.00236***	0.00209***	0.00234***
	(0.000675)	(0.000602)	(0.000621)	(0.000608)
Log (real sales)	0.00549		0.0124	
	(0.00620)		(0.00800)	
GVC firm	0.0311*	0.0310*	0.0437***	0.0296*
	(0.0172)	(0.0161)	(0.0155)	(0.0160)
Log (age)	−0.0202***	−0.0180***	−0.0270***	−0.0222***
	(0.00632)	(0.00553)	(0.00741)	(0.00660)
Log (TFP)	0.00430	0.00389	0.00211	0.00502
	(0.00874)	(0.00773)	(0.00808)	(0.00871)
HHI	0.0547***	0.0576***	0.0620***	0.0479***
	(0.0148)	(0.0138)	(0.0148)	(0.0134)
Multi-prod firm	−0.000595	0.00150	−0.00414	0.00467
	(0.00692)	(0.00548)	(0.00716)	(0.00569)
Foreign firm	−0.0155		−0.0239	−0.0162
	(0.0269)		(0.0278)	(0.0265)
Foreign shares		−0.000903*		
		(0.000511)		
Standard errors	One step	Two-step with lag change	Two-step	Two-step
Time FE	yes	yes	yes	yes
Observations	12,446	12,446	10,810	10,810
Number of firms	2,527	2,527	2,137	2,137
Number of instruments	46	32	46	40
Hansen's *p* val	0.130	0.593	0.098	0.358
AR (2)	0.526	0.574	0.785	0.715

Note: Constants and year dummies not reported. Time fixed effects are included in all models. Models 3 and 4 are run on a sub-sample of firms which report sales of at least Rs.1 million and employ more than 10 workers.

Table A10. Robustness checks with different measures of vertical specialisation: log(PS).

Variables	Model 1	Model 2	Model 3	Model 4
L.Log (PS)	0.788***	0.795***	0.802***	0.795***
	(0.0479)	(0.0477)	(0.0458)	(0.0474)
L2.Log (PS)	0.0807*	0.050	0.0891*	0.0582
	(0.0436)	(0.0441)	(0.0464)	(0.0458)
Log (vs2)	0.00763**	0.0063*		
	(0.00377)	(0.0037)		
Log (vs3)			0.00699*	0.00695*
			(0.00412)	(0.00404)
Log (age)	−0.0140**	−0.005	−0.0104*	−0.00481
	(0.00563)	(0.004)	(0.00626)	(0.00518)
Log (employment)	0.00838*	0.0017	0.00738	0.00297
	(0.00501)	(0.005)	(0.00623)	(0.00583)
Foreign shares	0.000200	0.00019	0.000174	0.000189
	(0.000192)	(0.00018)	(0.000246)	(0.000204)
Log (R&D intensity)	0.00121*	0.00057	0.000661	0.000362
	(0.000706)	(0.00056)	(0.000979)	(0.000631)
HHI	0.00586	0.015**		0.0122*
	(0.00712)	((0.0064)		(0.00643)
Multi-product firm		0.004		0.00416
		(0.0040)		(0.00448)
Log (labour prod.)		0.0113		0.0133
		(0.008)		(0.00908)
High tech. sector		0.0435***		0.0407***
		(0.0089)		(0.0087)
Constant	0	0	0.389***	0
	(0)	(0)	(0.151)	(0)
Time fixed effects	yes	yes	yes	yes
Observations	11,523	11,175	10,676	10,385
Number of firms	1,950	1888	1,801	1,750
No. of instruments	50	50	39	46
AR(1)	0.000	0.000	0.000	0.000
AR(2)	0.555	0.230	0.660	0.301
Hansen *p* val	0.055	0.706	0.073	0.130
Sargan *p* val	0.173	0.091	0.169	0.258

Note: VS2 excludes import of services and VS3 excludes import of capital goods and services. Standard errors are two-step robust, clustered on firms.

Table A11. Robustness checks with import content of exports; log(PS).

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
L.Log (PS)	0.786***	0.767***	0.774***	0.791***	0.781***	0.789***
	(0.0398)	(0.0434)	(0.0409)	(0.0410)	(0.0434)	(0.0409)
L2.Log (PS)	0.132***	0.134***	0.132***	0.125***	0.110**	0.109**
	(0.0395)	(0.0404)	(0.0415)	(0.0462)	(0.0471)	(0.0476)
Log (ICE)	0.0255***	0.0197**	0.0215**	0.0242***	0.0154*	0.0193**
	(0.00903)	(0.00856)	(0.00880)	(0.00874)	(0.00838)	(0.00822)
Log (age)	−0.0166***	−0.0151***	−0.0123**	−0.0161***	−0.00911*	−0.0113**
	(0.00537)	(0.00506)	(0.00500)	(0.00495)	(0.00497)	(0.00494)
Log (employment)	0.0110**	0.0103**	0.00915*	0.00935*	0.00398	0.00427
	(0.00500)	(0.00490)	(0.00526)	(0.00542)	(0.00538)	(0.00550)
Foreign Firm		0.0215	0.0230	0.0238	0.0163	0.0233
		(0.0160)	(0.0160)	(0.0161)	(0.0160)	(0.0155)
HHI			−0.00171	−0.00271	0.000819	0.000950
			(0.00731)	(0.00721)	(0.00700)	(0.00736)
Multi-product firm			−0.00757*	−0.00779**	−0.00584	−0.00322
			(0.00395)	(0.00393)	(0.00394)	(0.00393)
Log (R&D intensity)				0.00103	0.00112	0.000804
				(0.000760)	(0.000770)	(0.000806)
Log (labour prod.)					0.0115	0.00514
					(0.00827)	(0.00822)
High tech. sector						0.0193*
						(0.0108)
Time FE	yes	yes	yes	yes	yes	Yes
Observations	11,802	11,743	11,380	11,380	11,380	11,380
No. of firms	1,998	1,979	1,916	1,916	1,916	1,916
Instruments	33	39	41	41	45	42
AR (2)	0.503	0.496	0.539	0.679	0.934	0.957
Hansen's *p*-val	0.310	0.113	0.130	0.151	0.058	0.074
Sargan's *p*-val	0.590	0.561	0.576	0.417	0.186	0.158

Note: Data is from panel B (GVC firms) for the period 2010–2015. Import content of export = (import of raw materials + import of stores and spares + import of capital goods + import of services)/total exports. Standard errors are two-step robust, clustered on firms. Time fixed effects and constants are included in all models but coefficients are not reported. AR(1) = 0 for all models.

Note: Data is from panel B (panel of only GVC firms) for the period 2001–2015. VS1 = [(import of raw materials + import of stores and spares+ import of capital goods+ import of services) / (raw material expenses+ SS consumed+ GFA+ total expenses on services)] * export intensity. Standard errors are two-step robust, clustered on firms. A second period lag of product sophistication has been introduced to ensure stability of the model. Time fixed-effects and constants are included in all models but coefficients are not reported. AR(1) = 0 for all models.