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How deep is your love?

Innovation, Upgrading and the Depth of Internationalization

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Abstract: Global Value Chains (GVCs) provide an important opportunity to become member of the global economy. Gaining access to GVCs and the possibility of developing linkages with major suppliers and customers enables the prospect to upgrade products and production processes via knowledge and technological spillovers, learning by doing and the allocation of new task. Adopting new production technologies and realizing synergy effects might allow cost reduction, product innovation and product upgrading. Even if GVCs represent a rich environment for innovation activities, the extent to which knowledge is created and transferred among firms may vary considerably across their mode of participation in the global chain, thus resulting in heterogeneous innovation capacities for the firms involved. Differences in the forms of governance underlying buyer-supplier relationships – for instance linked to dissimilar power asymmetries and firm capability – can strongly affect the knowledge transmission along the chains and are potentially able to explain heterogeneities in firms' innovation propensity. Using a firm-product-level dataset of Indian manufacturing firms including information on business groups, this paper contributes to recent studies on international production and GVCs by testing the effect of different modes of internationalization on firms' upgrading activities, including the extensive and intensive margins of innovation and R&D expenditures. Controlling for the selection bias associated with the chosen mode of internationalization and accounting for potential reverse causality, this paper shows that the deeper firms are integrated internationally, the higher the likelihood that they engage in innovation activities. Firms which have a high mode of internationalization are not only more productive, but also more likely to introduce new products, upgrade existing products and produce more sophisticated products than firms that are less engaged in international markets and, thus, less prone to international competition.

Keywords: Global value chain, exporting, importing, FDI, innovation, upgrading
JEL codes: F23; F61; O31; D22; L23; f14

1. Introduction

Globalization and the proliferation of global value chains (GVCs) have become the defining feature of today's international trade. Technological progress, decreasing trade barriers and declining trade costs have promoted the fragmentation of production across regions and continents[1]. Policy makers from various developing countries have carried out wide ranges of outward-oriented economic reforms in order to promote domestic economic productivity and to stimulate the acquisition of global capabilities. Two major features of such policy reforms are the liberalization of trade and foreign direct investment. As a result, firms in countries that liberalized their markets were able to rapidly increase their presence in international markets and attract foreign direct investments. Thus, these reforms opened the door for enterprises to establish global linkages and integrate into GVCs.

With deeper integration of developing countries into global markets, firms in these countries face as well increasing competitive pressure. Firms in developing countries, in common with firms everywhere, are under pressure to improve their performance and increase their competitiveness. Facing international competition, producers aiming to maintain or increase income and productivity must either increase the skill content of their activities and/or move into market niches, which have entry barriers and are, therefore, isolating them to some extent from international pressure. Nevertheless, international integration also offers the opportunity for developing countries to get access to technologies and knowledge. The integration into global networks might facilitate the diffusion of knowledge across boundaries. Gaining access to GVCs and developing linkages with major supplier and customers enables the possibility for innovation and upgrading via knowledge and technological spillovers, learning by doing and the allocation of new task, which is of particular importance for a developing economy. Adopting new production technologies and realizing synergy effects might allow cost reduction, product innovation and product upgrading.

Even if GVCs represent a fertile environment for upgrading, the extent to which knowledge is created and transferred among companies may vary considerably across their modes of participation in the chain, thus resulting in heterogeneous upgrading capacities for the firms involved. Differences in the forms of governance underlying buyer-supplier relationships –for instance linked to dissimilar power asymmetries and firm capability– can strongly affect the

[1] See Gereffi & Fernances-Stark (2016)

knowledge transmission along the chains and are potentially able to explain heterogeneities in firms' upgrading propensity. Multinational companies are more willing to transfer knowledge to skilled partners[2] to reduce the risk of "residual incompatibilities" between the product design and the components manufactured. However, while the absence of strong ties with other companies implies on one hand a high degree of autonomy (and, thus, fostering upgrading), on the other it also limits the possibility of knowledge exchanges with partner firms.

The aim of this paper is to take various dimensions of innovation and internationalization into account, drawing attention to policy variables enhancing or discouraging GVC participation and innovation. We aim to investigate how the environment in which firms operate in accordance with firm-specific efforts and actions shapes the innovation pattern of enterprises.

Using a firm-product-level dataset of Indian manufacturing firms, this paper contributes to recent studies on international production and GVCs by testing the effect of different depth of GVC participation on firms' innovative activities. Due to its rapid economic progress and its successful market liberalization and integration in to the global economy, India offers an excellent case study to evaluate the relation between technological adaption, innovation and GVC participation. This paper extends previous work by considering various depth of GVC integration and a broad range of measures for innovation activities. Besides the expenditures on Research and Development (RnD) activities and the increase thereof, we take into account as well product innovation, process innovation, product upgrading, functional upgrading and intersectoral-upgrading while controlling for the selection into GVCs and various firm characteristics. Our findings suggest that the deeper the integration into GVCs the more likely a firm will engage in innovation activities. Controlling for the selection bias associated with the chosen mode of internationalization and accounting for potential reverse causality, this paper shows that the deeper firms are integrated internationally, the higher the likelihood that they engage in innovation activities. Firms which have a high mode of internationalization are not only more productive, but also more likely to introduce new products, upgrade existing products and produce more sophisticated products than firms that are less engaged in international markets and, thus, less prone to international competition.

[2] They like to use their acquired partners more effectively within the GVC agreements.

Policies aiming at increases in the skill level help to facilitate the successful integration into GVCs and encourages innovation, not only for firms integrated in GVCs[3]. Thus, such policies might be able to spur innovation across firms, increase productivity and efficiency, and promote growth.

This paper is organized as follows. Section 2 briefly discusses related studies on the impacts of GVC participation on innovation. Section 3 describes the identification of the depth of GVC participation and the different innovation activities in detail. This section provides as well an overview of the data and its distribution across GVC depths and different innovation activities. Section 4 explains the empirical methodology used to estimate the impact on various innovation activities conditional on the depth of GVC integration, modelling the selection into GVCs explicitly. Section 5 presents and discusses the results of the analysis of the determinants of GVC participation, and the estimated average treatment effects of different depth of GVC integration on various innovation measures covering the extensive and intensive margin. The last section concludes.

2. Background

The relation between GVCs, firm performance and corporate innovation has been extensively debated. There is a vast amount of theoretical and empirical literature that investigates determinants of innovation and their consequences for productivity, economic growth and – to a smaller extent – for trade. Learning by exporting and spillovers from foreign direct investment (FDI) have shown how international linkages play a crucial role to access technology and knowledge, which are crucial for innovation (Girma et al, 2004; Harding & Javorcik, 2012; Humphrey & Schmitz, 2002; Van Biesebroeck, 2005). Typically, exporters and firms are found to be more productive than non-exporters and domestic firms, and the more productive firms self-select into participating in international markets (Helpman et al, 2004; Melitz, 2003)[4].

Besides from these internationalization effect on firm performance, participation in GVCs can also benefit innovation activities. For example, exporters have access to knowledge flows and

[3] Available human capital spurs innovation created within the firm. In contrast, an increase in the skill level seem to discourage process innovation which uses technologies, licenses and knowledge from outside the firm.

[4] The empirical literature dominantly uses micro data from different economies with mixed results (see among others Clerides et al (1998); Girma et al (2004); Van Biesebroeck (2005)). Learning-by-exporting might not necessarily be present. Haidar (2012) using Indian data spanning mainly the time briefly after the Indian investment and trade liberalization starting in 1992, does not find evidence for learning-by-exporting effects in India. For a detailed literature survey see Wagner (2007).

technologies not available in domestic markets which not only impacts performance but as well innovation activities. Exporting is associated with higher innovation activities since larger markets provide higher returns to innovation investments and the evolution of a firm's profitability improves by innovation activities. Aw et al (2008) provide evidence that the probability of investing in RnD increases with experience in exporting activities. Salomon & Shaver (2005) stress that exporters have more product innovation and file more patent applications[5]. Lileeva & Trefler (2010) demonstrate that Canadian firms that started to export or exported more after the elimination of US tariffs displayed a higher rate of technology adoption and innovation. Costantini & Melitz (2007) and Raff et al (2011) modelled the dynamics of trade liberalization and the anticipation thereof which increase a firms' innovation activities in order to participate in international trade. Helpman et al (2007) focus on the design of contracts: the greater the contractual incompleteness, the less advanced technologies get adapted.

The recent literature in international economics focuses in particular on the role of product and process innovation. Product innovation is seen as key element of firm growth, successful market entry and creative destruction. Process innovation, in contrast, is expected to secure a firm's market position given its product characteristics. Becker & Egger (2013) provide evidence that firms that perform both process and product innovation have a higher propensity to export than firms that do not innovate. Meyer (2016) shows that firms that become foreign owned have a higher propensity to engage in product innovation and product upgrading. Eck & Huber (2016) find spillover effects from foreign direct investment through supplier linkages on the manufacturing of sophisticated products. Multinational enterprises are able to provide technology inputs like know-how, technical assistance, as well as investments and the adoption of capital equipment necessary for innovation (Franco et al, 2011; Lall, 2002).

Similar effects are found by the literature focusing on the identification of GVC and the nature of interfirm organizations within value chains (Brancatia et al, 2017; Gereffi & Fernances-Stark, 2016; Humphrey & Schmitz, 2002). This literature stresses that it is not enough to focus on one mode of internationalization: growth opportunities of a firm are as well effected by the specific way and intensity of participating in the global production process. The extent of exchange of information, the extent of knowledge and technology transmission and adaption

[5] They use Spanish manufacturing firms from 1990 to 1997.

varies considerably across the depth of GVC integration (Pietrobelli & Rabellotti, 2011). Environments with complex transactions and high-skill suppliers are regarded as ideal for process upgrading (Humphrey & Schmitz, 2002). Despite the large amount of literature examining global production networks, the majority of empirical papers focuses on firm specific case studies or are limited to specific industries[6]. Most studies at the firm level focus on productivity, output growth and sales (see e.g. Baldwin and Yan(2014); Pietrobelli and Salionla (2008), Salionla and Zanfei 2009 Kummritz et al (2017)). An exception are Brancatia et al (2017) who analyse the impact of Italian firms in GVCs on innovation and performance during the Great Recession. They show that high-skill relational suppliers fared the crisis by engaging in product and process innovation and higher investments in RnD projects while other firms in lower modes of GVC participation have no premium compared to domestic companies.

In the case of India, earlier studies have found positive spillovers from exporting on RnD expenditures in the context of the liberalization reforms implemented during the 1990s (Kumar & Aggarwal, 2005). Competitive pressure pushed Indian plants into RnD activities (Pradhan, 2002). Lancheros (2016) shows that the higher the export intensity of Indian pharmaceutical firms, the higher the rates of technology adoption. Higher RnD intensity can be observed for firms affiliated to business groups (Purkayastha et al, 2016; Singh & Gaur, 2013). Highly diversified international business groups enjoy larger economies of scale, access to complementary resources and technologies that facilitate the adaption of innovation capabilities in the global economy. Ashwin et al (2015), for example, conjecture that innovation in form of RnD investments and patent application in the Indian pharmaceutical industry was facilitated by a high technology opportunity environment within business groups.

In contrast to these studies, this paper focus on a range of activities related to innovation and does not consider only one single indicator of innovation. Using firm level data for all Indian manufacturing firms, this paper wants to combine different approaches and looks at the intensive and extensive margin of innovation as consequence of GVC participation, taking explicitly the selection into GVCs into account. This is important, since economic theory suggests that firms do not select into GVCs and undertake innovation activities at random, neither product innovation, product upgrading, functional upgrading nor intersectoral

[6] See among others Giuliani et al (2005) and Morrison et al (2008).

upgrading. Further, the environment firms operate in, including various industrial policies, is taken into account in the analysis of the effect of the GVC participation and innovation.

3. Data

To identify GVC participation and innovation activities, this paper focuses on firm-level information from Indian manufacturing firms from the Prowess database collected by the Centre for the Monitoring of the Indian Economy (CMIE). Prowess contains information primarily from income statements and annual reports of publicly listed companies. The data spans the years from 1990 to 2013, thus, it includes as well the period of India's trade and investment liberalization phase. Prowess provides detailed firm-level information for a panel of medium and large manufacturing firms accounting for around 70 percent of economic activity in India's formal industrial sector (see Goldberg et al (2010a; 2010b).[7] The panel structure of Prowess enables within and across firm comparisons of restructuring activities, performance changes and innovation activities over time. Though the panel is unbalanced, firms used in the analysis are usually observed for a continuum of at least four years after entering the database.

3.1 Characteristics of Global Value Chain Involvement

The detailed firm level information allow to measure the depth of GVC integration. A firm's involvement in GVCs is identified by looking at the complexity of a firm's internationalization strategy as reflected by how many international activities they deploy in combination, similar to the definition of Veugelers et al (2013).

If a firm is puely domestically owned, does not engage in exporting or importing activities it is considered as a firm **not participating** in a GVC. If a firm exports only a small share of its output, its imports account only for a limited fraction of total imports or the firm has only limited linkages to international networks it is defined as firm with **limited** access to GVCs. The access to international networks is in this context defined, as being majority foreign owned, owning foreign affiliates with a major share abroad or being part of a domestic or foreign business group which is highly active in international trade. A lot of Indian firms engage in business groups[8], e.g. the Tata Group and the Birla Group are two famous examples. These two

[7] The dataset does not include small firms. However, the exclusion of small firms does not affect our analysis since mainly medium and large firms are integrated in GVCs and undertake the majority of innovation.
[8] A business group is defined by promoter stake holding, equity ownership holding of a particular individual or family or management control. However, one should note that there is no strict rule to classify a business group.

Indian multinational conglomerates have a widespread domestic and international network and are highly active in exporting and importing activities. Within such business groups technological transfers and knowledge spillovers might facilitate innovation activities, in particular if they also operate internationally. While remaining an independent enterprise, member firms of business groups have several horizontal connections such as cross-shareholding, interlocking directorates and social ties, and vertical connections through shared ownership and control. Members in such business groups are usually deeper connected via regional or global value chains than members outside the group. Though a firm in a business group might only export or import a small share by itself, it might do so much more intensive indirectly on arm's length. Often firms form a conglomerate in which one member is a trade agency[9] through which the firms in the respective group take part in the international market. Firms in such conglomerates are integrated in various depth in GVCs.

In general, firms that export at least two thirds of their total output are regarded as intensive exporters. Firms that import at least one third of their total material inputs import intensively. Firms that are either majority foreign owned, majority own affiliates abroad, or are member of an intensive international trading business group[10] are regarded as well linked internationally to supplier and customer networks. Firms that fulfil one of these three conditions (intensively exporting, intensively importing or being well linked internationally) are considered to be integrated into GVCs at a relatively **low** depth. Firms that fulfil two of these three conditions are regarded as participating in an **intermediate** depth in GVCs. Firms that export intensively, import intensively and have well established global linkages are regarded as **high**ly integrated into GVCs (triple mode of GVC integration). Table 1 provides details on the definitions and identification strategies of various depth of GVCs.

Almost three quarter of all medium and large Indian manufacturing firms involve in GVC at least in a limited fashion. Around 34 percent of all manufacturing firms engage in GVCs in a limited depth with only a small share of exports, imports and limited international linkages, more than one quarter of Indian manufacturing firms engage intensively in international markets either by importing, exporting or by having well established international production

[9] A trade agency is defined as firm operating in the whole sale and retail sector (NIC code 45, 46 and 47) and exports more than 80 percent of its sales.
[10] These are groups that import more than two thirds of the total material inputs group wide or exports at least two thirds of their total group wide output.

Table 1: Overview and Identification of GVC modes

Depth / Mode of participation	Description	Identification	Share of firms
High / Triple	Domestic or foreign firms that are linked to GVCs with high Import-Content-of-Export (ICE) and also developed international production networks (high level of inter firm-linkages).	The firm needs to fulfil all three requirements: (1) Total value of imported inputs > 1/3 of total inputs, (2) the firm exports > 2/3 of total sales and (3) is majority foreign owned, has a majority stakes in companies abroad, or belongs to an international orientated business group (total exports of the group > 2/3 of total output or total imported inputs of the group >1/3 of total inputs).	1.35%
Intermediate/ Dual	Domestic or foreign firms that are actively part of GVC via trade linkages. These firms have a significantly high Import-Content-of-Export (ICE) or have established inter-firm linkages via investment activities.	The firm needs to fulfil two out of the three requirements: (1) Export share of total sales > 2/3 (2) Total value of imported > 1/3 of total production costs. (3) majority foreign ownership, majority stakes in companies abroad, or belonging to an international orientated business group (total exports of the group > 2/3 of total output or total imported inputs of the group >1/3 of total inputs)	9.29%
Low/ Single	Domestic or foreign firms whose engagement in GVCs is limited to a single internationalization mode.	The firm needs to fulfil one out of the three requirements: (1) Export share of total sales > 2/3 (2) Total value of imported inputs > 1/3 of total input cost (3) majority foreign ownership, majority stakes in companies abroad, or belonging to an international orientated business group (total exports of the group > 2/3 of total output or total imported inputs of the group >1/3 of total inputs)	28.21%
Limited	Domestic or foreign firms whose engagement in GVCs is limited in terms of intensity with respect to exporting, importing, inter-firm linkages. These firms with are mainly orientated towards the domestic market.	The firm exports share is < 2/3, imported inputs < 1/3 and it has no majority foreign ownership or majority stakes in companies abroad and no international orientated business group linkages (total exports of the group < 2/3 of total output or total imported inputs of the group < 1/3 of total inputs)	34.36%
No	Domestic or foreign firms with no engagement in GVCs not belonging to the four types described above. These firms are only oriented toward the domestic market.	Residual category of intermediate good producing firms.	26.78%

Note: The given percentages of firms and the total numbers of firms is calculated without explicitly taking the time dimension into account. The total number of firms is 11,917.

networks. Nearly 10 percent of firms have engage in GVC at an intermediate level. And only a small share of 1.4 percent of firms engage highly in GVCs. They have direct foreign relationships reflected in their business organization: they export and import intensively and are well connected to international production networks via high levels of inter firm-linkages.

The prevalence of the mode of internationalization varies across sectors and locations[11]. The sectoral distribution of firms across GVC modes is displayed in Table 7. Table 7 reveals that in particular industries which are high-tech related have a deeper integration into GVCs than industries which are rather agricultural related. While more than 45 percent of all firms in the food and beverage industry are not integrated into global markets, not even 10 percent of firms in the computer industry are only active within the domestic markets. Firms in the computer, electrical equipment, other machinery, automobile, other transport equipment, furniture and others show a high international connectedness: they engage in trading activities and build multinational firm networks. Firms in the other transport equipment sector are dominantly organized in business groups, either domestic ones in which firms heavily export and import, or foreign business groups which as well source and supply foreign business partners.

The garment industries are well connected in international distribution networks. They are in particular highly active in exporting activities, independent of their local wholesale and retail activities. Firms in these industries export typically a major share of their sales, directly or at arms-length.

Noteworthy is as well the automobile industry which is highly engage in regional and global value chains. More than three quarters of all firms in the automobile industry engage at least with a single mode in international markets.[12]

Firms that are deeply integrated into GVC are usually bigger and matter substantially for aggregate performance of the sectors. As can be seen from

Table 2, firms deeper integrated in GVCs are typically larger in terms of output, pay higher wages, have a higher productivity, are more established and employ a higher skill level[13].

[11] One should note that firms tend to cluster in economic centers in India. Large and medium sized firms can mainly be found in Gujarat, Maharashtra, NCT of Delhi, Tamil Nadu, West Bengal, Telangana, and Karnataka.
[12] Though, one should note that in the dataset are in total 45 different firms in the automobile sector.
[13] Skills are approximated as wage per value added.

Table 2: Average Output, wage, age, productivity, financial leverage and the skill level for different depth of GVC integration

GVC Mode	Output	Wage	Age	Productivity	Leverage	Skill
No	1.187	0.159	20.713	-0.149	1.271	0.029
Limited	2.277	0.550	22.609	0.040	1.562	0.147
Low	2.585	0.739	25.525	0.059	1.502	0.295
Intermediate	3.087	0.989	25.947	0.094	1.616	0.392
High	3.019	0.867	25.931	0.189	1.656	0.298
Mean	2.157	0.544	24.839	0.002	1.473	0.183
No of observations	73098	73098	72836	73098	72411	72128

Note: Calculation based on all years. Output and wage are in Indian Rupees (logged and deflated). Productivity is measured by log tfp. Financial leverage is measured as liabilities to equity ratio and the skill level is approximated by wage per value added.

Figure 1 shows the kernel-density functions[14] of productivity with respect to different modes of GVC participation and confirms that firms with deeper GVC integration have on average a higher productivity. The superior performance of this highly integrated firms is particularly visible in the upper tail of the distribution, i.e. firms with a high mode of GVC integration are not only more likely to have on average a higher productivity, they are especially likely to be among the best performers[15].

Firms integrated in the global production process are not only the larger firms, they also matter substantially for aggregate performance of sectors within India. As Figure 2 shows, firms in GVCs dominate the Indian economy by producing more than 95 percent of total output. The major output share, nearly half of the total output is produced by firms in a relative low mode of GVC integration. Firms which are integrated into global production networks at intermediate or high level account for more than half of total manufacturing exports. The 1.4 percent of firms which are deeply engaged in GVCs account for about 6 percent of total output and for nearly 15 percent of total exports.[16]

[14] Since the tfp distribution is skewed, it is preferred to look at the full distribution of tfp levels rather than only average values. A kernel density shows the shares of firms (density) that reach each productivity level, thus it shows the probability of choosing a firm with a certain productivity level when firms are randomly drawn from each category of GVC activities.

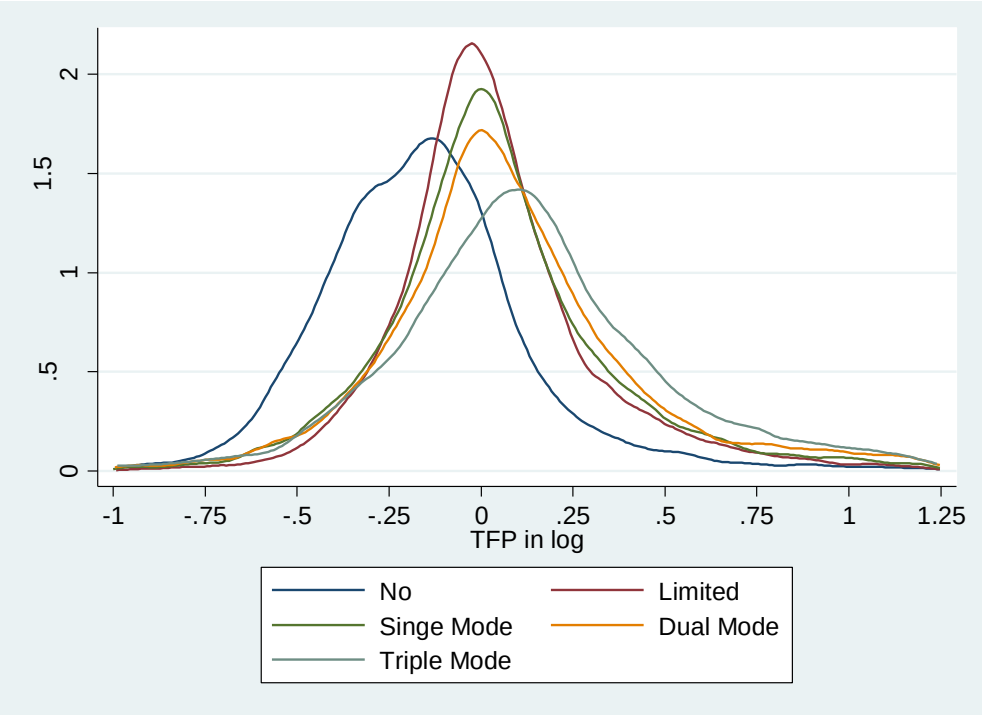
[15] This is true for all manufacturing industries. See Figure A1 in the appendix for the kernel densities for Apparel and Textiles, and Electronics.

[16] This distribution is similar in all manufacturing industries.

3.1 Innovation Activities

The most common proxy of innovation are the expenditures on research and development activities. However, there are different types of innovation and upgrading activities. Besides the expenditures on **Research and Development** (RnD) activities[17] and the increase thereof, we take into account several definitions of upgrading and innovation activities, based upon the extensive and intensive margins of innovation. Namely, we look at the intensive and extensive margin of process upgrading, product innovation, product upgrading, functional upgrading and intersectoral upgrading.

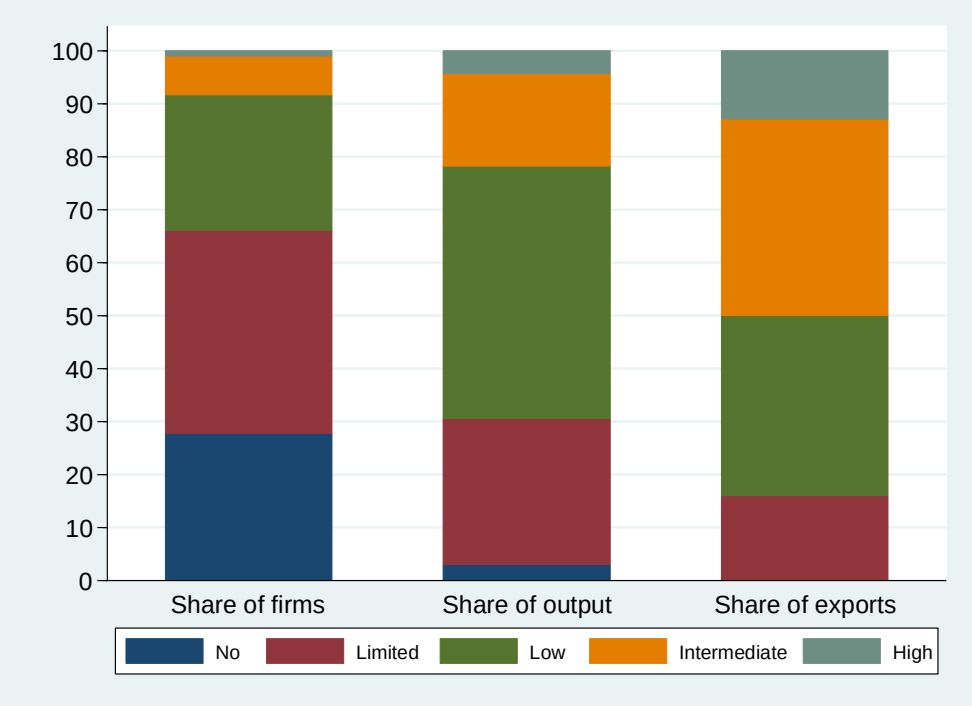
Figure 1: Total Factor Productivity density and different modes of internationalization



Note: Tfp is constructed following the methodology of Levinsohn & Petrin (2003).

[17] Many firms in the dataset do not report whether they encounter R&D expenditures or not.

Figure 2: Distribution of firms, output and exports according to different modes of integration into Global Value Chains



Note: Tfp is constructed following the methodology of Levinsohn & Petrin (2003).

Due to the 1956 Indian Companies Act to disclose product-level information on capacities, production and sales in their annual reports, a firm's product mix can be traced over time. Product-level information is available for about 80 percent of the manufacturing firms and the product-wise sales comprise 98 percent of the individual reported manufacturing output.[18] Since product-level information on sales and quantity are reported for each product, Prowess is particularly well suited to analyse the effects of GVC mode changes as well on product innovation, the quality of products and the sophistication level of products. Thus, with this dataset the underlying mechanism of firm-level adjustments in response to ownership changes and international trade participation that are typically hidden in other data sources can be quantified while not being prone to measurement issues arising at the firm level or with survey data. The product level information allows to track whether firms introduced new product to their product mix, upgrade their products, increased their product quality or sophistication level.

[18] Like Goldberg et al (2010a), we cross-checked this information. Since product-level information and overall sales information are provided in different data modules, this can be validated easily. The fiscal year ends usually in March in India, such that a particular year refers to the fiscal year-end that occurs in the following March. Several companies report different year end values. In order to render all companies comparable, companies with a year end up to July are assumed to refer to the previous year's result. Further, products deviating from their usual production cycle in one year (for example only 3 month instead of 12 month) are dropped to ensure comparability.

In the following, the definition and identification of each of these measures is briefly described.

3.1.1 Innovation Measures

A firm can be innovative by **upgrading its processes** by reorganizing the production system or introducing superior production technologies to transform inputs into outputs more efficiently. Products vary substantially in terms of how they are produced both within sectors and across sectors (See among others Goldberg et al (2010b)). Since often licensing or patents for superior technologies or processes are needed, this can be approximated by fees payed for technical know-how and patents. Further, increases in expenditures of capital good, i.e. new machinery, intangible assets and other equipment and accessories required for production of goods either directly or indirectly might lead to process upgrading. New technologies used in the production process are usually acquired through the purchase of capital goods. Therefore, these two indicators, fees payed for royalties and the expenditures for capital goods are used to capture expenditures on process upgrading.

A firm can engage in **product innovation** by introducing new products to the product scope. Due to the detailed product level information, the addition of products to the product mix can easily be tracked in the Prowess dataset. The definition of a product[19] is based on the CMIE's internal product classification which builds on the Indian Trade Classification and Harmonized Commodity Description and Coding System. The internal CMIE product classification can be mapped to the Indian National Industrial Classification (NIC) 2008 which is comparable to the International Standard Industry Classification (ISIC) Revision 4 up to the four-digit level. This mapping allows to assess product disaggregation and diversification at a very detailed level. There are 1729 products (at the five-digit product level) linked to 113 four-digit NIC industries across 23 sectors (two-digit NIC codes). The product coverage is similar to the U.S. (see Bernard et al (2010))[20]. As Meyer (2016) shows, foreign owned firms produce on average more diversified and sophisticated products and are more like to engage in product innovation activities. On average a firm in a high GVC mode produces on average around 6 products while domestic firms produces around 4 products.

[19] An example for the product classification of Prowess is given in Table A 1 in the appendix.
[20] The definition of a product is slightly more detailed than the definition used by Bernard et al (2010) for U.S. manufacturing data. Their data contains approximately 1500 products, defined as five-digit Standard Industrial Classification (SIC) codes, across 455 four-digit SIC industries. At the most disaggregated level, Prowess contains in total 3820 different products in the manufacturing sector.

Further, firms can engage in **product upgrading** by moving into higher quality product lines. If firms upgrade their products, the quality of the products, and, thus, the price of the product increases. The quality of the products produced can be approximated by the unit value of the respective product.

Firms can not only increase the quality of their produced products, but as well focus on higher value added activities. **Functional upgrading**, that is acquiring new superior functions in the value chain can be proxied by the average sophistication level of products produced. To determine the level of sophistication of products, the product-specific sophistication index from Hausmann et al (2007)[21] is adapted. This index measures the average implied technology level of a certain product, *k*, which is proxied by the average GDP per capita of those countries that export this particular product *k*. If richer economies have on average a revealed comparative advantage in the production of a product, this product is associated with a higher sophistication level. Thus, the index reflects the technology intensity of a product that an economy must meet in order to be able to compete internationally. According to Hausmann et al (2007), the level of sophistication of product k is defined as

$$SOPH_{tk} = \sum_{c} \left(\frac{x_{ctk}/X_{ct}}{\sum_c x_{ctk}/X_{ct}} \right) Y_{ct} = \sum_{c} \varphi_{ktc}\, Y_{ct}$$

where x_{ctk} represent country c's export volumes of product k at time t, X_{ct} are the total exports of country c in period t with total endowments, measured as GDP per capita, Y_{ct}. Since the numerator of the weight of the factor endowments of a country is the value-share of product k in a country's overall export basket and the denominated of the weight are the value-shares across all countries exporting the product k, the weights φ_{ktc} correspond to the revealed comparative advantage of each country in the production of good k[22]. Data on GDP per capita in constant 2010 US Dollar are from the World Development Indicators database. Data on product-level exports are from the CEPII-BACI database which is constructed from the UN Comtrade data[23]. We use disaggregated export data at the 4-digit-ISIC Revision 4 level to be able to match the sophistication level to the products of the Indian firms. The extend of product

[21] This is the extensively used PRODY index by Hausmann et al (2007).
[22] The weights are a variant of the Balassa's Revealed Comparative Advantage (RCA) Index and add up to one. This ensures that a country size does not distort the sophistication ordering of the products. For more details, see Hausmann et al (2007).
[23] Downloaded on 15/05/2017.

sophisticate per firm is measured as sales-weighted average sophistication level of all products, $k = 1, \dots, K$, that are produced by an Indian firm i at time t:

$$SOPH_{it} = \sum_{k}^{K} \frac{Sales_{kit}}{\sum_{k}^{K} Sales_{kit}} SOPH_{kt} \ .$$

Thus, an increase in $SOPH_{it}$ indicates that a firm increased its production of products with higher sophistication level or focused more on sales of its sophisticated products. Overall, an increase in the average sophistication level, thus reflects that firms concentrate more on higher value-added products by upgrading its production function.

Moreover, firms can acquire particular functions which enable them to move into a new sector, potentially sectors with higher technology content. Entering into a completely new sector or industry using knowledge acquired through production of other product or specialized services typically requires multiple upgrading strategies to occur simultaneously or in sequence in order to enter the new industry successfully. This **intersectoral upgrading** is measured by shifts in the core competency of a firm. Since Prowess allows to track the manufactured goods over time, shifts in the core competency and, thus, the major sector of production can be identified. Shifting the core competency of a firm into sectors with higher technological intensity is the result of restructuring the processes of production in order to benefit more from synergy effects and economies of scale. Adapted from Meyer (2016) shows foreign owned firms tend to concentrate more on producing products together in more technology intensive sectors. Similar effects can be found for firms sourcing globally: in particular firms who participate in global markets at intermediate and high depth focus their production much more on a core competency and produce more similar products in more technology intensive sectors together[24].

3.1.2 Innovation Activities of Indian Firms

Table 3 provides detailed information on the distribution of various innovation activities among Indian firms. Firms not participating in GVCs invest on average only 0.08 Mio. Indian Rupees in RnD while those firms which are deeply integrated in global production networks spend on average 3.66 Mio. Indian Rupees on RnD. Though these firms account only for roughly two

[24] Technology intensity of sectors is measured according to the OECD classification scheme (see http://www.oecd.org/sti/ind/48350231.pdf, last accessed 01/07/2017). See
Table A 2 adopted from Meyer (2016) for product produced together in different sectors by firms in the highest mode of GVC participation and firms not integrated into GVCs.

percent, these triple moders account for around 8 percent of total RnD expenditures. More than half the share of total RnD expenditures (nearly 55 percent) is invested by firms participating with a relatively low depth (single mode) in GVCs. Firms engaging in a limited or low fashion in GVCs increase their share of RnD expenditures on average the most over time.

In similar lines, around 36 percent in the double and triple mode engage in process innovation, while only roughly 5 percent of purely domestic firms engage in process innovation. Double and triple moders spend more than one third of all cost for royalties and more than 43 percent of accumulated cost for capital goods. A quarter of firms in the low mode of GVC integration engaging in process innovation accounts for more than half the costs for royalties and around 40 percent of expenditures for capital goods. Firms that focus purely on the domestic market and do not engage in GVCs account for not even one percent of these expenditures.

Firms are also quiet heterogeneous with respect to product innovation. Firms not participating in global production networks produce on average less number of product, they produce on average 3.4 products while firms integrated in international production produce on average 5.4 products. They are also more likely to introduce new products to the market. On average, 20 percent of the firms in GVCs engage in product innovation. In contrast, only 13 percent of firms not in GVCs introduce new products to the market.

On average half of the firms engaging in GVCs increased their product quality over the sample period, while only 44 percent of domestic firms engaged in product upgrading.[25] The deeper firms are integrated in global sourcing, the higher their quality. If firms in the triple mode upgrade their product quality, in half of the cases it leads to an increase in higher than average product quality.

Firms integrated in GVCs produce on average not only products with higher quality but as well with higher sophistication levels. The average sophistication level of the production sector is higher for firms integrated deeper in production networks on the global scale. More than 53 percent of the triple moders even increase their production sophistication level during the time of observation. At limited depth, firms still engage in 44 percent over time in functional upgrading.

[25] Product quality is approximated by deflated unit values.

Successful intersectoral upgrading is relatively rare since it involves different innovation activities simultaneously. Only around 4 percent of all firms engage in intersectoral upgrading. Firms deeper integrated in global sourcing have on average already a high technology intensity. While the majority of purely domestic firms with domestic orientation are categorized with a low technology intensity level (1), the majority of firms which participate at intermediate or high level in GVCs have a technology intensity categorized as medium-high (3) or high (4). The relatively aggregated measure for technology intensity and the fact that many firms in GVCs engage in relatively technology intensive industries leaves not much room for observing this type of innovation more frequently. However, the trade and investment liberalization in India enabling Indian firms to become part of GVCs seems to also affect the core sectors of production of purely domestic firms. They have a significantly higher share of experiencing decreases in technology intensity when switching the sector.

Table 3: Innovation and GVC participation

	No	Limited	Low	Inter-mediate	High	Total
RnD expenditures						
RnD expenditures	73.99	2627.38	8778.42	3302.61	1341.99	16124.39
Share of RnD expenditures	0.46	16.29	54.44	20.48	8.32	100
No of Firms	925	6966	7131	3067	367	18456
Average RnD expenditure	0.08	0.38	1.23	1.08	3.66	0.87
Share of Firms which increase their RnD expenditures	3.87	36.45	39.59	18.00	2.09	100
Process Innovation						
Royalties	274.15	2364.98	10314.81	6286.80	175.64	19416.38
Expenditures for Capital Goods	733.11	12506.08	30405.27	28966.70	4179.94	76791.09
No of Firms engaging in Process Innovation	1012	4881	5294	2501	353	14041
Share of Firms in the resp. mode	5.17	19.41	25.67	36.75	35.69	19.20
Product Innovation						
Mean no products	3.40	5.25	5.52	5.97	4.19	4.91
No of Firms	2637	5028	4088	1403	177	13333
Share of Firms in the resp. mode	13.48	19.99	19.82	20.61	17.90	18.23
Product Upgrading						
No of Firms engaging in product upgrading	6234	10338	8334	2803	378	28087
Share of Firms in the respective mode	44.36	48.56	49.09	49.87	51.29	47.87
No of Firms producing higher than average quality	3177	3562	3257	1185	190	11371
Share of Firms in the resp. mode	16.24	14.16	15.79	17.41	19.21	15.55
Functional Upgrading						
Average Level of Sophistication	13154.26	15752.58	15645.68	16504.09	16441.49	15111.31
No of Firms **increasing the level of Sophistication**	8279	11006	9480	3227	524	32516
Share of Firms in the resp. mode	42.31	43.77	45.97	47.41	52.98	44.46
Intersectoral Upgrading						
Average Technology Intensity	1.857	2.212	2.297	2.525	2.622	2.18
No of firms engaging in intersectoral upgrading	520	906	751	235	18	2430
Share of Firms in the resp. mode	2.66	3.60	3.64	3.45	1.82	3.32
No of Firms engaging in intersectoral downgrading	2931	2065	1605	434	43	7078
Share of Firms in the resp. mode	14.98	8.21	7.78	6.38	4.35	9.68

Note: The given percentages of firms and the total numbers of firms is calculated without explicitly taking the time dimension into account. Total number of observation is 72128.

4. Empirical approach

This section describes the empirical approach. There are two main issues which have to be taken into account in assessing the effects of the depth of the integration in GVCs on firms' upgrading and innovation propensity. First, more dynamic firms might self-select themselves into different modes of integration in GVCs. It is well documented, that there is a productivity gap between different modes of internationalization (see among others Helpman et al (2004)). Foreign acquired firms are ex ante more productive, younger, larger, less leveraged and pay higher wages (see among others Harris & Robinson (2003); Javorcik & Arnold (2009)). Second, the integration into GVCs might not promote upgrading and innovation activities but are rather the consequences of successful innovation activities.

Thus, we proceed in a two-step estimation procedure. First, we model a selection equation to quantifying which firm characteristics determine the mode of integration into GVCs. Then, we model the relation between innovation and the depth of integration into GVCs taking the selection into GVCs into account.

4.1 Selection into Global Value Chains

We estimate the probability that a firm chooses a certain mode of internationalization as a function of a set of firm characteristics and fixed industry and time characteristics. Thus, the probability of choosing a certain depth of GVC integration is estimated by

$$\mathbf{Pr}(\boldsymbol{mode_{ist}}) = \boldsymbol{\phi}(\boldsymbol{\beta_0} + \boldsymbol{\Gamma_1}(\boldsymbol{Z_{ist-1}}) + \boldsymbol{\Gamma_2}(\boldsymbol{P_{st-1}}) + +\boldsymbol{\delta_t} + \boldsymbol{\delta_s} + \boldsymbol{\delta_i}) \quad (1)$$

where $mode_{ist}$ is the chosen depth of GVC integration of firm i operating in sector s at time t. In the following analysis, the mode of GVCs is classified according to Table 1 as zero, low, single, dual, and triple modes of internationalization. The mode of GVC integration is a function of firm characteristics Z including a firms' size measured by its output level, age, the skill level approximated by its wage per value added[26], total factor productivity (tfp) and financial leverage[27] as a proxy for access to finance. As shown before, it is necessary to accounted for

[26] The wage bill is measured in logs relative to the size of a firm.
[27] Financial leverage is measured by the ratio of liabilities to equity.

these firm characteristics since larger, more established, more productive firms are usually engaged deeper in GVCs.

Tfp is constructed following the methodology of Levinsohn & Petrin (2003) [28]. To estimate the production function consistently, firm level labour, capital and materials are needed. Since Prowess does not have reliable employment information, the total wage bill[29] is used to measure labour inputs. Gross fixed assets[30] including movable and immovable assets measure capital inputs. All relevant values are deflated using all-Indian wholesale sector-specific price indices provided by the Office of the Economic Adviser of the Indian Ministry of Commerce and Industry[31].

Besides these variables at the firm level, certain policies at the national and state level might influence the participation in GVC by facilitating and promoting e.g. exporting activities. The vector P includes such variables like special economic zones (SEZ), an important instrument to support export activities in certain regions. SEZ are sector specific and measured at the state level.[32] Additionally, the vector P accounts for the agglomeration of certain sectors in certain states, which influences a firm's domestic market share and market size. Sectoral agglomeration at the state level is measured by the Herfindahl-Hirschman Index (HHI) using the shares of firms output in a sector. To account for possible comparative advantages of a certain sector, the sectoral export output ratio of are taken as well into account.

Further, firm fixed effects (δ_i) to control for time invariant firm characteristics, sector fixed effects (δ_s) to account for sector specific heterogeneity[33] and year fixed effects (δ_t) to capture unobserved aggregate shocks are included in the estimation of (1). This selection equation is estimated using an ordered logit model.

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[28] Assuming a Cobb-Douglas production function, the estimated equation for company i operating in sector s at time t is $y_{ist} = \alpha_0 + \alpha_k k_{ist} + \alpha_l l_{ist} + \alpha_m m_{ijt} + \beta_e e_{ist} + \omega_{ist} + \eta_{ist}$ where y_{ist} refers to firm i's output at time t, k is the capital stock, l is labor and m are intermediate inputs and e is energy used. All variables are expressed in natural logarithm. The respective time-varying productivity shock of firm i represented by ω_{ist} and the measurement error in output, uncorrelated with input choices, is η_{ist}.

[29] The total wage bill includes bonuses as well as contributions to employees' provident funds.

[30] Gross fixed assets constructed by the perpetual inventory method rather than net fixed assets are used since no detailed information on the economic rate of depreciation are available for the Indian manufacturing industry.

[31] Retrieved from http://www.eaindustry.nic.in/home.asp (13/05/2017).

[32] Retrieved from http://sezindia.gov.in/writereaddata/pdf/notified.pdf (17/06/2017).

[33] Firms can switch their main industry. In these cases, the industry a firm is mainly operating in, that is the industry accounting for most of a firms sales and most of its products, is used to account for industry specific characteristics.

Due to the large number of firms relative to the time dimension, estimating equation (1) with fixed effects in the traditional fashion leads to an incidental parameter problem (due to the large number of dummies) and, thus, to biased and inconsistent estimates. Therefore, a random effect ordered logit model corrected for the within firm variation by averaging each firm level regressor over time. This approach, motivated by Mundlak (1978) and Chamberlain (1980), accounts for fixed effects by relaxing the strong assumption of independence between the firm unobserved heterogeneity and the set of covariates. By holding the time averages fixed for the covariates, it allows to estimate the effects of changes in the variables.[34]

4.2 Innovation and the Mode of Internationalization

Superior productivity, which is a major factor of engaging in GVCs, is often acknowledged as an important driver for innovation. A deeper GVC integration can therefore be expected to boost firm performance and initiate innovation activities since it grants access to more efficient sourcing, larger markets and technology.

The baseline specification tests the existence of upgrading premia for firms in global and national value chains, and analyses heterogeneities across the different modes of GVC integration. Thus, when considering determinants for innovation activities, it is necessary to take the mode of internationalization into account. Innovation activities are typically associated with

$$I_{ist} = \beta_o + \beta_{GVC} mode_{ist-1} + \Gamma(Z_{ist-1}) + \Gamma_2(P_{st-1}) + \delta_t + \delta_s + \delta_i + \mu_{ist+\tau} \qquad (2)$$

where I_{ist} represents the different innovation measures as introduced in the previous section. $mode_{ist}$ measures the GVC mode of firm i. The vector Z captures structural firm characteristics including productivity, size, age, financial capabilities and the market share and strategic

[34]This approach follows Wooldridge (2010) based on the devices of Mundlak (1978) and Chamberlain (1980) to relax the assumption on the correlation between the unobserved heterogeneity and the repressors (Z) (i.e. $\delta_i|Z \sim N(\mu + \bar{z}_i, \sigma_a^2)$). This approach is similar to a fixed effects model in which the heterogeneity is projected on the time-mean of the repressor ($\bar{Z}_i$) allowing to write the latent variable as $Y_{it}^* = \mu + \beta^T Z_{it-1} + \theta^T \bar{Z}_i + e_{it}$, with $e_{it} \sim N(0,1)$. Since this estimator depends crucially on the exogeneity of Z_{it-1} conditionally on δ_i, we test whether this assumption holds for individual repressors with testing the significance of the estimated coefficients of the respective means. Since the test never rejects the null hypothesis, we are ensured that the strict exogeneity assumption holds.

characteristics like the skill level, a learning effect from the experience in the respective GVC-depth (approximated by time in the respective GVC mode[35]).

Besides these variables at the firm level, certain policies at the national and state level might influence the likelihood of engaging in innovation activities e.g. by competition policies or promotions of high tech industries. The vector P includes therefore variables like the Herfindahl-Hirschman Index (HHI) to proxy for concentration and competition in the respective sector a firm is operating in. Higher competition might force firms to engage more in innovation activities.[36] Moreover, the average skill intensity of sectors measured as wage share of a sector.

Further, firm fixed effects (δ_i) to control for time invariant firm characteristics, sector fixed effects (δ_s) to account for sector specific heterogeneity[37] and year fixed effects (δ_t) to capture unobserved common time varying shocks are included in the estimation of (1).

Two major concerns arise when assessing the effects of GVCs on firms' innovation propensity. First, the GVC participation might not foster upgrading processes but instead might be themselves the consequence of successful upgrading. To mitigate reverse causality issues and to rule out a simultaneity bias, lagged values of the respective modes of GVCs and firm level characteristics are used in the estimation process. To further reduce endogeneity concerns in the binary response framework prone to an incidental parameter problem (when the time span is small relatively to the number of observations in the cross section), the estimation of (2) might lead to inconsistent estimates in the fixed-effects-model. Our strategy to obtain consistent estimates is to apply the "Mundlak-Chamberlain" correction as well in this estimation process for bivariate outcomes.

To take care of self-selection into GVCs matching techniques are used to recover a subsample of firms with the same ex ante probability of GVC participation (matched according to equation (1)). We then re-estimate equation (2) weighted with the inverse propensity scores obtained from equation (1) for the subsample of balanced firms to make inference on the effect of being

[35] In case the firm is in the respective GVC mode since it entered the database, the proxy is set to the maximum time span this firm is observed in the dataset according to its age and the first time it appeared in the database (max 25 years).
[36] Aghion et al (2005) show that competition encourages particularly neck-and-neck firms to innovate while at the same time discourages laggard firms from innovating.
[37] Firms can switch their main industry. In these cases, the industry a firm is mainly operating in, that is the industry accounting for most of a firms sales and most of its products, is used to account for industry specific characteristics.

part of a GVC on the respective innovation activity and provide robustness to our results[38]. To ensure that the treatment effect can be identified, the overlap (or common support) condition is imposed, that is the probability of being in a certain depth of GVC integration with depth $d \in \{low, limited, intermediate, high\}$ conditional on the determinants of GVC integration (see equation (1)) is bounded between zero and one.[39] A series of balancing tests confirms that the propensity score matching is successful in controlling for firm differences.[40] To obtain the average treatment effect (ATE) of being part of a GVC at depth d, the potential innovation outcome of participating in a certain depth of GVCs is compared to the potential innovation outcome if the firm had not taken part in the respective depth in a GVC is calculated, i.e.:

$$ATE = E\left(I_{ist}^{d} - I_{ist}^{no}\right) \tag{3}$$

where d indicates the respective depth of GVC integration. The potential outcome of each treatment, $\widehat{I_{ist}}$, is predicted based on the estimates of (2). By setting $mode^{d}$ equal to one for all observations the potential net effect on the respective innovation activity is obtained, by setting $mode^{d}$ equal to zero the potential outcome of no participation in GVCs is obtained:

$$\widehat{I_{ist}^{d}} = \Phi\left(\widehat{\beta_0} + \widehat{\beta_d} + \hat{\Gamma}(Z_{ist-1}, P_{ist-1})\right) \text{ and } \widehat{I_{ijt}^{no}} = \Phi\left(\widehat{\beta_0} + \hat{\Gamma}\left(Z_{ijt-1}, P_{ist-1}\right)\right) \ . \tag{4}$$

In the final step of the doubly robust procedure, the ATE is calculated as the average difference between these two potential outcomes:

$$ATE = \frac{1}{N}\sum_{i=1}^{N}\left(\widehat{I_{ist}^{d}} - \widehat{I_{ist}^{no}}\right) . \tag{5}$$

The ATE provides the premium connected to being integrated internationally at depth d related to the respected innovation activity.

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[38] The propensity scores are computed according to Lechner (2002) and Girma et al (2015). The propensity score sets each predicted probability for each depth of GVC participation, π_{ist}^{d}, relative to the base category of no GVC participation : $p_{ijt}^{d} = \frac{\pi_{ijt}^{d}}{\pi_{ijt}^{d} + \pi_{ijt}^{no}}$ where d indicates the respective depth of GVC integration $d \in \{low, limited, intermediate, high\}$.

[39] Hence, the combination of observed covariates can also be found among domestic firms.

[40] Due the large number of tables, the detailed test on the matching are not shown here. They can be received from the author on request.

5. Results

Before discussing the impact of being deeply integrated in global networks, we look at the propensity of engaging in different depth in GVCs. Having validated our selection equation, we use these results to account for selection in the estimation of the impact on different innovation activities.

5.1 Selection into GVCs

Table 4 reports the results of the estimation of equation (1). The multivariate analysis correcting for firm and industry characteristics confirms a significant and sizeable impact of productivity on the choice of GVC integration. The higher a firm's productivity, the larger a firm and the higher the average wages, the more likely a firm integrates deeper in international markets.

Figure 3 shows the relation between the productivity of a firm and the probability of engaging in a GVC mode. Tfp is highly correlated with a more complex international integration indicated by a higher mode of GVC involvement. This shows that the productivity premium of firms is intrinsically connected to a deeper GVC involvement, that is, firms with higher productivity typically engage in export, import activities, engage with foreign investors or go by themselves abroad. The lower the productivity, the higher the probability of not engaging internationally. The bulk of firms with low productivity are either not participating at all in GVC or in a rather limited fashion. The majority of firms in the median range of productivity are most likely to choose only one mode of internationalization. Firms with high productivity are typically found at an intermediate or high level of GVC integration.

For a one unit increase in tfp, the odds of engaging in a triple mode of GVC integration are around 2.22 times larger than engaging in a low, single or dual mode of GVC integration. On average, an increase in tfp by one standard deviation decreases the probability of staying purely domestically and not engaging internationally by 10.3 percent points, while it increases the probability by 13.2 percent points to engage in a dual mode of GVC integration and 8.2 percent points to engage in the triple mode of GVC integration for Indian firms[41].

[41] These changes in the probabilities are obtained from marginal effects evaluated at the means; i.e. productivity=1.0760, age=23.6778, size=2.1791, leverage=0.4385, skill=0.1325, market share= 0.0247, SEZ=0.26733, export share = 0.1543 and competition = 0.0276. A change by one standard deviation in tfp corresponds to a change by 0.406.

Table 4: Odds ratio of engaging in GVCs with different modes

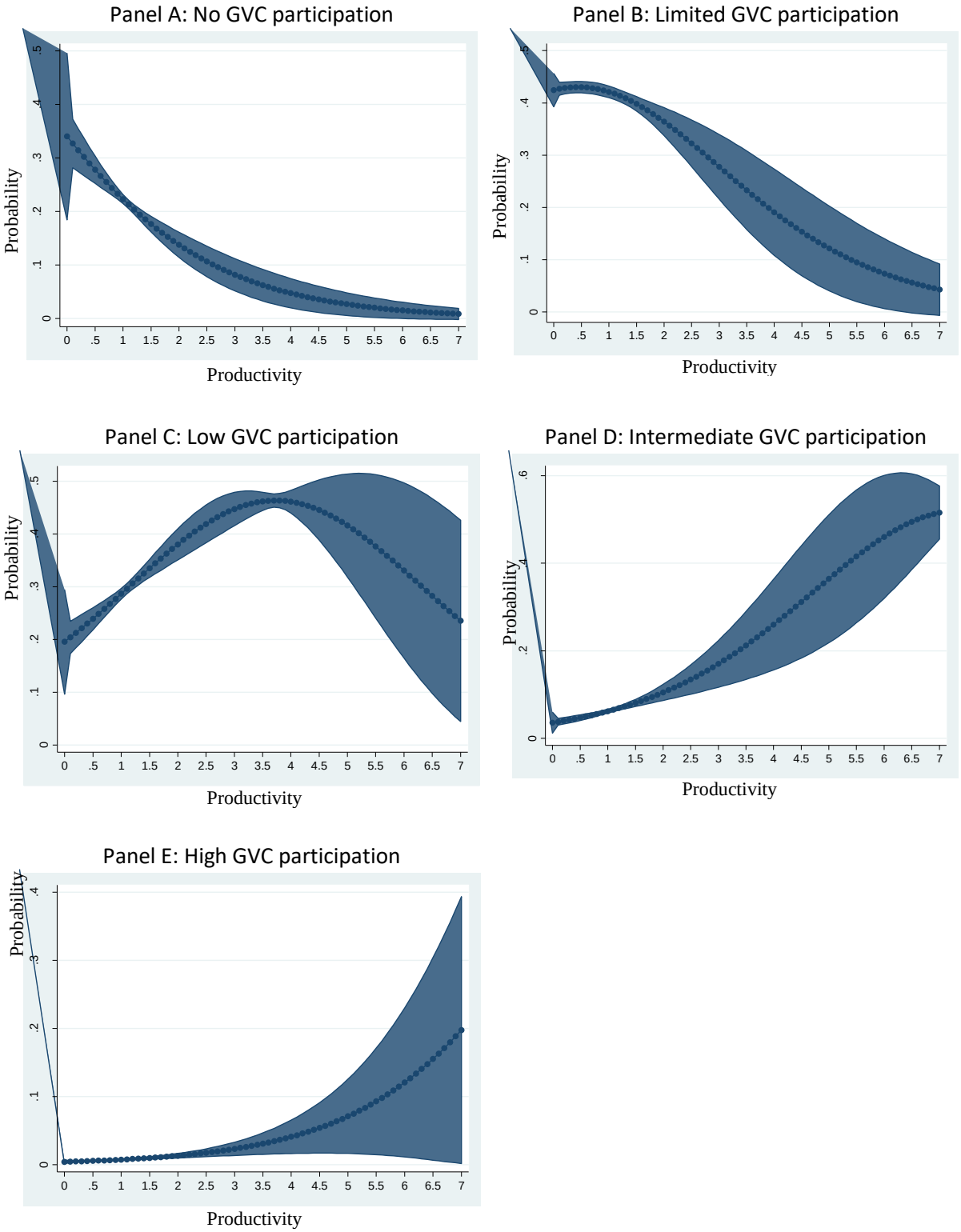
	(1)	(2)	(3)	(4)
Tfp	1.2670**	1.4573***	1.4204***	1.4132***
	(0.1350)	(0.1531)	(0.1477)	(0.1488)
Age	1.0672***	1.0556***	1.0564***	1.0768***
	(0.0083)	(0.0082)	(0.0081)	(0.0108)
Size	1.5371***	1.5115***	1.5131***	1.5152***
	(0.0435)	(0.0433)	(0.0420)	(0.0435)
Financial Leverage	0.9495	0.9665	0.9611	0.9658
	(0.0306)	(0.0317)	(0.0305)	(0.0319)
Skills	1.0104	1.0091	1.0098	1.0088
	(0.0112)	(0.0074)	(0.0077)	(0.0074)
Market Share			0.4813**	0.5969*
			(0.1375)	(0.1780)
Special Economic Zones			1.0446	1.0102
			(0.0440)	(0.0373)
Export Advantage			3.5383***	1.9419**
			(0.8012)	(0.5429)
Competiton			0.0001***	4.4478***
			(0.0001)	(1.0793)
Fixed Effects	Firm (MC) Year Sector State	Firm (MC) Year-Sector State	Firm (MC) Year Sector State	Firm (MC) Year-Sector State
Number of Observation	64,315	64,315	64,315	64,315
Log Likelihood	-71694	-73891	-73969	-73639
Pseudo R2	0.145	0.149	0.148	0.142

Notes: Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level. Firm heterogeneity is captured with the Mundlak-Chamberlain device as described in the text.

The marginal effects for the respective likelihood of participating in a certain depth in GVCs are shown in Table 4Table 5. The likelihood of participating in global production and global sourcing drastically increases with productivity increases. A marginal unit increase in productivity makes a firm by 10 percent less likely to only serve and produce for the domestic market. An increase by one marginal unit increases the propensity of engaging in the low mode of GVCs by around 10 percent, the propensity of engaging in the intermediate mode by around 3 percent and the propensity of engaging in the high mode by around 1 percent.

Besides productivity, the size of a firm matters. The larger a firm, the more likely it faces international competition by integrating into GVCs. A marginal change in size raises the likelihood by 2 percentage points to engage in a dual mode and by an additional percentage point to engage in a triple mode of GVC integration. A marginal increase in size lowers in turn the probability of only acting purely domestically by on average 13.7 percentage points, and

Figure 3: The probability of engaging in a GVC mode conditional on the total factor productivity



Note: The probability of the GVC mode is estimated by equation (1) holding all other variables constant at their means (Means: age = 23.6778, size = 2.1791, leverage = 0.4385, skill = 0.1325, market share = 0.0247, SEZ = 0.26733, export share = 0.1543, competition = 0.0276). Confidence Intervals at the five percent level are depicted in blue.

increases the probability of engaging in a low or single mode of GVC integration by 8.4 and 3.4 percentage points on average.[42]

The age of the firm and the associated (domestic) market experience influence as well the decision to join the international markets. Gaining more experience on the market increases the likelihood to integrate intensively at least in a uni-model way in GVCs by around 12 percent. One year more experience in the markets increases the likelihood to move to a higher mode of integration on average by around 5 percentage points.

The impact of the average skill level and the market experience of a firm are relatively small and not statistically significant.

Table 5: Marginal Effects of participating in the respective GVC depth

	No	Limited	Low	Intermediate	High
Productivity	-0.1090***	-0.0369***	0.0968***	0.0347***	0.0144***
	(0.0179)	(0.0069)	(0.0175)	(0.0063)	(0.0009)
Age	-0.087***	-0.033***	0.0855***	0.031***	0.004***
	(0.0013)	(0.0005)	(0.0013)	(0.0005)	(0.0001)
Size	-0.0706***	-0.0226***	0.0593***	0.0212***	0.0127***
	(0.0051)	(0.0022)	(0.0050)	(0.0019)	(0.0003)
Leverage	0.0067	0.0025	-0.0066	-0.0024	-0.0003
	(0.0054)	(0.0020)	(0.0052)	(0.0019)	(0.0002)
Skill	-0.0023	-0.0008	0.0022	0.0008	0.0001
	(0.0023)	(0.0009)	(0.0023)	(0.0008)	(0.0001)
Market Share	0.1277***	0.0476***	-0.1249***	-0.0447***	-0.0057***
	(0.0478)	(0.0180)	(0.0468)	(0.0168)	(0.0022)
SEZ	0.0073	0.0027	0.0072	0.0026	0.0003
	(0.0071)	(0.0026)	(0.0069)	(0.0025)	(0.0003)
Export Advantage	-0.2052***	-0.0765***	0.2006***	0.0719***	0.0092***
	(0.0381)	(0.0150)	(0.0375)	(0.0135)	(0.0019)
Competition	-0.6056***	-0.5983***	0.5698***	0.5624***	0.0717***
	(0.2179)	(0.0872)	(0.2126)	(0.0791)	(0.0115)

Note: Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level. Marginal effects of participating in the respective GVC mode calculated based on equation on the estimation of the specification in column (3) of Table 4. The marginal effects are evaluated at the means (Means: productivity= 1.0760, age = 23.6778, size = 2.1791, leverage = 0.4385, skill = 0.1325, market share = 0.0247, SEZ = 0.26733, export share = 0.1543, competition = 0.0276).

[42] This is calculated based on average changes based on the marginal effects shown in Table 5.

Additionally, industrial policies seem to promote the integration into GVCs. Firms which can exercise a monopolistic power in their industry are more likely to engage as well in foreign markets. Being located in a SEZ seems not to influence the decision of engaging in direct trade and interacting with foreign investors[43]. Further, operating in sectors which display a comparative advantage in exporting increases the likelihood of firms to engage deeper in GVCs. Firms in sectors which display a high export ratio in general are also inclined to participate in a deeper mode of GVC integration than those in sectors with a low export advantage. [44]

Looking at industrial differences, sectors involving more advanced technologies are more likely to integrate in deeper GVC modes. In particular, those firms within the electronics sector which are highly productive have are much more likely to choose the triple mode of GVC integration. In contrast, for sectors that are rather labor intensive the size of the firm matters more than the productivity. For those firms, competition policies seem to be as well of big importance: An increase in the industry agglomeration increases the probability to engage in a single or double mode by 14 percentage points. Thus, industrial policies enhancing the competition might lead to a market orientation beyond the domestic market and increase the likelihood of directly exporting and importing.

5.2 Innovation

Propensity scores as weights for the estimation of equation (2) are calculated based on the outcome in column (3) of Table 4[45].

Table 6 shows the ATE of GVC integration in different depth on different innovation activities. In general, deeper integrated firms have a higher propensity to engage in various innovation activities. In particular firms, with intermediate and high modes of integration are much more likely to engage in innovation. They are the firms which seem to benefit most from potential knowledge and technology spillovers. Strong trading connections and/or being well linked to

[43] Note, that this might be the result of a too broad measure for SEZ which are usually defined for specific industries in small areas encompassing cities or regions and not at the broad state and sector level.

[44] Table A 3 in the appendix shows detailed estimation on GVC participation for the textile and apparel sector and the electronics sector.

[45] Propensity scores have to satisfy the overlap condition and numerous test were taken out to such that the sample is balanced with respect to propensity scores. Observations which did not satisfy the overlap condition or lead to an unbalancedness of the sample were drop from the estimation procedure.

international networks seem to spur innovation. In particular, firms integrated in an intermediate depth, i.e. firms that are integrated in a dual mode of GVC participation are the ones which seem to benefit most across different innovation activities compared to their domestically orientated counterparts.

In the following, we will look at each innovation measure separately.

Table 6: Average Treatment Effect of the depth of GVC participation on different innovation activities

	ATE of				Predicted Outcome for NO GVC participation	Number of Obser-vation
	Limited GVC depth	Low GVC depth	Inter-mediate GVC depth	High GVC depth		
Increase in RnD expenditures (0/1)	0.0604***	0.0812***	0.1216***	0.0621**	0.0614***	57,135
	(0.0099)	(0.0100)	(0.0183)	(0.0259)	(0.0096)	
Expenditures on RnD	0.1124***	0.1470***	0.2182***	0.0929***	0.0899***	57,135
	(0.0182)	(0.0183)	(0.0242)	(0.0325)	(0.0180)	
Process Innovation (0/1)	0.1178***	0.1545***	0.2371***	0.1090***	0.0832***	57,136
	(0.0159)	(0.0160)	(0.0264)	(0.0324)	(0.0156)	
Expenditures on Process Innovation	0.1338***	0.2224***	0.4402***	0.1879***	0.0577***	57,136
	(0.0139)	(0.0144)	(0.0661)	(0.0539)	(0.0135)	
Product Innovation (0/1)	0.0423***	0.0524***	0.0416***	0.0195***	0.1902***	60,063
	(0.0100)	(0.0097)	(0.0131)	(0.0067)	(0.0092)	
Product Dropping (0/1)	0.1105***	0.1015***	0.1319***	0.1834***	0.5462***	61,885
	(0.0127)	(0.0130)	(0.0162)	(0.0353)	(0.0121)	
Number of Products	0.1475***	0.1056***	0.1119***	-0.1526***	1.2141***	61,885
	(0.0180)	(0.0185)	(0.0237)	(0.0556)	(0.0172)	
Product Upgrading (0/1)	0.0843***	0.0896***	0.0649*	0.1280**	0.3466***	57,136
	(0.0188)	(0.0191)	(0.0346)	(0.0544)	(0.0185)	
Functional Upgrading (0/1)	-0.0060	0.0181	0.0347*	0.0363*	0.4821***	57,136
	(0.0170)	(0.0172)	(0.0192)	(0.0152)	(0.0165)	
Intersectoral Upgrading (0/1)	0.0051	0.0064	-0.0073	-0.0123*	0.0323***	55,862
	(0.0109)	(0.0120)	(0.0108)	(0.0092)	(0.0118)	

Note: Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

5.2.1 RnD expenditures

Already a limited GVC depth increases the likelihood to increase the expenditures on RnD compared to firms focusing only on domestic markets not integrated in international production networks. Indian firms with an intermediate depth of GVC participation have a 12.2 percent higher propensity to increase their expenditures on RnD compared to domestic firms not integrated into GVCs.

A detailed look at the determinants of RnD expenditures and the increase thereof (see Table A 4 in the appendix) reveals that besides the GVC mode, an increase in output, productivity and the skill level enhances the likelihood to increase the expenditures on RnD. Further, the longer a firm is active in GVCs the more likely it becomes to increase its expenditures on RnD. One additional year in the GVC increases the likelihood in the limited or low mode of integration by more than 3 percent. However, the amount of total RnD expenditures seems to be only slightly effected (increase by not even 1 percent) by learning effects in GVCs.

Looking at the policy variables, reveals that the introduction of SEZs has a negative impact on the propensity to increase the RnD expenditures for firms in GVCs. The deeper they are integrated, the stronger the negative impact on the propensity to increase the expenditures on RnD. Being in a SEZ seems to facilitate to import innovation from partners rather than being innovative in the plant in India[46]. High competition with a large number of firms operating in the same industry and having a high market share rather influences the extensity and intensity of RnD expenditures of firms not engaging in GVCs or engaging only in a limited depth in GVCs. If the average human capital in the sector increases, firms operating internationally are more likely to use these skills and invest in RnD. An increase in the average sectoral skill level increases the likelihood of increasing the amounts spend on RnD between 46 percent (limited GVC participation) and 106 percent (high GVC participation).

5.2.2 Process Innovation

Integrating into GVCs offers the possibility to obtain easier access to technology, machinery, knowhow and licenses. The better firms are integrated into GVCs the higher the likelihood that they engage in process innovation. Firms with an intermediate depth of GVC integration are more than 23 percent more likely to engage in process innovation than comparable firms not

[46] This is confirmed by looking at the impact of SEZ on expenditures on process innovation and the increase thereof. See section

integrated into GVCs. These firms have on average a 44 percent higher expenditure on royalties and technological capital goods. Even firms which operate internationally on a limited extensity benefit already from their international environment: they are 12 percent more likely to engage in process innovation and spend on average 13 percent more on process innovation than their domestic counterparts.

Table A 5 in the appendix shows the determinants of process innovation according to the depth of GVC integration. A higher output and a higher productivity increase the likelihood of engaging in process innovation and the amount spend on process innovation. The older a firm and the more indebted it is, the less it is willing to engage and invest in process innovation. Having a well-educated workforce decreases the likelihood of engaging in process innovation and reduces the amount spend on process innovation. Firms which have a good skill base are potentially less dependent on external sources to improve their production processes. Each additional year a firm gains experience in GVCs increases the likelihood of investing in process innovation by around 3 to 4 percent if a firm intensively participates in GVCs. However, the effect on additional expenditures on process innovation are rather small for these firms, an additional year of experience in GVCs only leads to an increase in expenditures on process innovation between 0.2 and 1.2 percent.

Firms which are located in a SEZ but are not part of a GVC seem to have a disadvantage compared to their counterparts which have access to technologies, knowhow, licenses and their likes often transferred through partnerships in GVCs. Indian firms in SEZ are around 8.5 percent less likely to engage in process innovation and spend on average 2.7 percent less on technologies, licenses and patents related to process innovation. Facing high competition within India only increases the likelihood of engaging in process innovation for domestic orientated companies. In line, firms focusing mainly on the domestic market, i.e. firms which do not at all participate in GVCs or only at a very limited extend, which have a high market share in their sector are also more likely to improve their competitive position by investing in more efficient processes. Though the extensive margin of process innovation is not influenced by domestic market concentration for firms which operate extensively internationally, the intensive margin of process innovation is affected by domestic markets: the expenditures on process innovation increases drastically if there is a high competition in the Indian market for firms which

participate in low, intermediate and high depth of internationalization in GVCs[47]. A higher human capital in the sector decreases the intensive and extensive margin of engaging in process innovation. In particular, firms that are participate at least with a single mode of internationalization in GVCs are less prone to obtain knowledge and technologies from outside the firm and are more likely to reduce the amount spend on technologies, knowhow and licenses from outside the company group.

5.2.3 Product Innovation

Firms integrated into GVCs are much more likely to conduct changes in their product composition. Firms in the limited, low and intermediate depth of integration are around 4 to 5 percent more likely to engage in the development of a new product and introducing this new product to their product scope. Firms in theses modes are also much more likely to engage in product deconstruction, they are between 10 to 13 percent more likely to drop products from their product mix compared to if they had not integrated in GVCs. They produce on average around one product more[48]. Firms integrated at the triple mode are only around 2 percent more likely to introduce a new product to their product mix compared to their domestic counterparts. The propensity that triple modes drop products from their product mix is around 18 percent. Controlling for selection and various firm and sector characteristics reveals that triple moders are much more focused around a core competency than their domestic counterparts: they produce on average 1.2 product less than their domestic counterparts.

Table A 2 reveals that triple moders are much more likely to produce goods of related sectors together and are thus much more focused around their core competency than their domestic counterparts. On average they produce much more technology intensive goods together than firms purely producing for the domestic market.

Looking at the determinants of product innovation, product deconstruction and the total number of products produced reveals that independently of the mode of GVC integration, size and productivity matter most for changes in the product mix (see Table A 6 and Table A 7 in the

[47] This could maybe reflect that these firms face an even tougher competition in international markets and therefore react relatively strong with respect to the amount invested in process innovation to a competitive measure. Though the impact of domestic competition on the likelihood of engaging is GVC participation is not significant, the coefficient is nevertheless positive and relatively large, likelihood of engaging in process innovation increases by 21 to 35 percent.

[48] This calculation is based on the respective means of the number of products depending on the mode of GVC integration.

appendix)[49]. An additional year in the GVC significantly impacts product innovation and, thus, the total number of products. One additional year in the global production network increases the likelihood of engaging in product innovation by around 0.26 for firms in GVCs. Though this effects seems rather small, this effect aggregates with each year in the GVC. After 10 years of experience in GVCs, firms in GVCs are around 2.6 percent more likely to add products to their product mix compared to firms not integrated into GVCs. This learning effect is of particular importance for firms with limited or low participation with respect to the total number of products produced. Employing a skilled workforce and the availability of a skilled workforce in the sector increases the probability of product innovation and increases the number of products produced.

Looking at the impact of the policy variables it seems as if industrial policy does not significantly contribute to product innovation. Instead, being in a SEZ might lead to a drop of products from the product mix of firms in GVCs. Potentially these firms might drop products from their product mix which are not related to their locational advantage of the SEZ. The number of products of firms in GVCs is significantly negatively influenced by being in a SEZ. High competition put pressure on firms to focus on their core competencies and produce efficiently. Therefore, firms are likely to reduce their product scope if their face high domestic competition.

5.2.4 Product Upgrading

Being in a GVC also affects the quality of products measured in terms of unit values. Firms engaged in GVCs stronger increased the prices of their products compared to their domestic counterparts. In particular firms highly integrated into GVCs are 34 percent more likely to engage in product upgrading. These firms seem to be more active in increasing the quality of their products due to higher knowledge spillovers.

The determinants of product upgrading can be found in Table A 8 in the appendix. In general, having a high debt to equity ratio decreases the likelihood of engaging in product upgrading. Interestingly, the major, significant driver for product upgrading are the employed skill level of a firm and the spillovers from being active in a GVC. The available human capital within the

[49] A squared term of productivity is included as additional explanatory variable in the estimation of equation (2) using product innovation, product deconstruction and the (log) number of products as dependent variable. This term is included to capture potential cannibalization effects among different products produced. An additional product in the product mix might harm the production of existing products.

firm and the sector contribute significantly to the decision to upgrade the products of a firm. Further, being in a GVC and acquire technologies and knowhow through the value chain, the ability to learn from the partners in the value chain and the available skills play a major role in the decision to engage in product upgrading.

If a sector has a major comparative advantage in exporting, firms operating in this sector are significantly more likely to do their best to keep the comparative advantage in producing specific products. Firms independently of their integration level into global sourcing are more likely to engage in product upgrading. Even firms with no GVC participation operating in a sector with a comparative advantage are 18.7 percent more likely to enhance their product quality compared to firms not operating in such sector. Firms with a high GVC integration operating in a sector with a comparative advantage are even 42.5 percent more likely to enhance their product quality compared to firms not operating in this sector.

5.2.5 Functional Upgrading

Compared to the previous innovation activities, the effect of participating in GVCs on the average level of sophistication of the products produced is relatively small. Only firms which operate internationally at least at an intermediate level of internationalization seem to significantly have a higher level of sophistication on average than firms not participating in GVCs. Firms with an intermediate and high depth of GVC participation are around 3.5 percent more likely to engage in functional upgrading activities than their domestic counterparts. Spillover effects in particular of foreign ownership are stronger, the deeper firms are engaged in internationalization.

In general, as shown in Table A 9 in the appendix, functional upgrading is determined mainly by size, available human capital and whether the firm operates in a sector which has a comparative advantage or is prone to high competition.

Skills at the firm and sector level seem to matter particularly for firms which are not or only limited or only low integrated into GVCs. Deeper integration into GVCs seem to spill knowledge and technology necessary to increase the average sophistication level of products of the firms. Firms integrated at an intermediate and high level of integration become with each year of gaining experience in international markets more than 2.5 percent more likely to engage in product sophistication. Thus, the longer firms operate in GVCs the more they seem to learn how to upgrade their products.

5.2.6 Intersectoral Upgrading

Successful intersectoral upgrading is rare and GVC participation seem not to influence the decision to fully change the sector a firm is operating in. In contrast, being highly integrated in international markets, seem to lower the probability of switching sectors. Though firms which are highly active in GVCs are more likely to engage in all other innovation activities than their domestic orientated counterparts, their deep integration with their focus of operation and production into the global production network makes them less likely to switch completely their line of production. Switching the industry could harm their position in the global production and, thus, harm their competitiveness position.

Table A 10 shows that high competition, not gaining a high share of operating profits, and not operating in a sector with a comparative advantage might induce firms to switch their core competency to a different sector with a higher technology content. However, the larger firms are, in particular if they operate in a high mode of GVC integration, the higher the skill level of their employees, and the longer their experience in GVCs the less likely firms are to switch sectors.

6. Conclusion

GVCs represent a fertile environment for upgrading, the extent to which knowledge is created and transferred among companies varies considerably across their modes of participation in the chain, thus resulting in heterogeneous upgrading capacities for the firms involved. This paper not only takes heterogeneity in GVC participation into account, it looks as well at the intensive and extensive margins of various innovation activities as consequence of GVC participation. Using a firm-product-level dataset of Indian manufacturing firms including information on business groups, this paper contributes to recent studies on international production and GVCs by testing the effect of different modes of internationalization on firms' upgrading activities, including the extensive and intensive margins of innovation and R&D expenditures.

Our findings suggest that the deeper the integration into GVCs the more likely a firm will engage in innovation activities. The higher a firm's productivity, the larger a firm and the higher its skill level employed, the more likely a firm integrates deeper in international markets. Additionally, from an industrial policy point of view, competition policies and export promotion policies seem to spur the entry in international markets. If a firm operates in a more diversified sector with a higher share of different industries and competition, it is more likely to not only focus on the domestic market and to integrate into GVCs to expand its market size

due to higher competition at home.[50] Further, operating in sectors which display a comparative advantage in exporting increases the likelihood of firms to engage deeper in GVCs and spurs product upgrading.

Controlling for the selection bias associated with the chosen mode of internationalization and accounting for potential reverse causality, this paper shows that the deeper firms are integrated internationally, the higher the likelihood that they engage in innovation activities. Firms which have a high mode of internationalization are not only more productive, but also more likely to introduce new products, upgrade existing products and produce more sophisticated products than firms that are less engaged in international markets and, thus, less prone to international competition. In particular, firms integrated in an intermediate depth, i.e. firms that are integrated in a dual mode of GVC participation are the ones which seem to benefit most across different innovation activities compared to their domestically orientated counterparts. Firms participating in GVCs benefit at different strength from spillover effects: they seem to have with each year of experience in GVCs better access to knowhow and technologies needed to innovate. In particular firms, with intermediate and high modes of integration are much more likely to engage in innovation. Firms in this mode which seem to benefit most from potential knowledge and technology spillovers. Strong trading connections and/or being well linked to international networks seem to spur innovation.

However, some industrial and state policies like SEZ or competiveness regulations seem not to influence the decision of firms to participate in GVC, but have adverse effects on some innovation activities of firms. A univocal policy to enhance innovation of firms participating in GVCs and firms not participating in GVCs is to increase the available human capital within firms and across sectors. Offering trainings and education to improve the available skills for firms would have large effects on all types of innovation at the extensive and intensive margin and encourages firms to join GVCs.

[50] However, one should note that firms which can exercise a monopolistic power in their industry are more likely to engage as well in foreign markets. Being located in a SEZ seems not to influence the decision of engaging in direct trade and interacting with foreign investors.

7. References

Aghion, P., Bloom, N., Blundell, R., Griffith, R. & Howitt, P. (2005) Competition and innovation: An inverted-u relationship. *The Quarterly Journal of Economics*, 120(2), 701-728.

Ashwin, A. S., Krishnan, R. T. & George, R. (2015) Family firms in india: Family involvement, innovation and agency and stewardship behaviors. *Asia Pacific Journal of Management*, 32(4), 869-900.

Aw, B. Y., Roberts, M. J. & Xu, D. Y. (2008) R&d investments, exporting, and the evolution of firm productivity. *American Economic Review*, 98(2), 451-456.

Bang, H. & Robins, J. M. (2005) Doubly robust estimation in missing data and causal inference models. *Biometrics*, 61(4), 962-973.

Becker, S. O. & Egger, P. H. (2013) Endogenous product versus process innovation and a firm's propensity to export. *Empirical Economics*, 44(1), 329-354.

Bernard, A. B., Redding, S. J., Schott, P. K. & Nichols, A. (2010) Multiple-product firms and product switching. *American Economic Review*, 100(1), 70-97.

Brancatia, E., Brancatib, R. & Maresca, A. (2017) Gvc, innovation and performace: Firm-level evidence from italy. *Journal of Economic Geography*(1-35).

Chamberlain, G. (1980) Analysis of covariance with qualitative data. *The Review of Economic Studies*, 47(1), 225-238.

Clerides, S. K., Lach, S. & Tybout, J. R. (1998) Is learning by exporting important? Micro-dynamic evidence from colombia, mexico and morocco. *The Quarterly Journal of Economics*, 113(3), 903-947.

Costantini, J. A. & Melitz, M. (2007) The dynamics of firm-level adjustment to trade liberalization, in Helpman, E., Marin, D. & Verdier, T. (eds), *The organization of firms in a global economy*. Cambridge: Harvard University Press.

Eck, K. & Huber, S. (2016) Product sophistication and spillovers from foreign direct investment. *Canadian Journal of Economics-Revue Canadienne D Economique*, 49(4), 1658-1684.

Franco, E., Ray, P. K. & Ray, S. (2011) Patterns of innovation practices of multinational-affiliates in emerging economies: Evidences from brazil and india. *World Development*, 39(7), 1249-1260.

Gereffi, G. & Fernances-Stark, K. (2016) *Global value chain analysis: A primer*. Duke University, North Carolina, USA: Center on Globalization, Governance & Competitiveness (CGGC).

Girma, S., Gong, Y., Görg, H. & Lancheros, S. (2015a) Estimating direct and indirect effects of foreign direct investment on firm productivity in the presence of interactions between firms. *Journal of International Economics*, 95(1), 157-169.

Girma, S., Görg, H. & Lancheros, S. (2015b) Investment liberalisation, technology take-off and export markets entry: Does foreign ownership structure matter? *Journal of Economic Behavior & Organization*, 116, 254-269.

Girma, S., Greenaway, D. & Kneller, R. (2004) Does exporting increase productivity? A microeconometric analysis of matched firm. *Review of International Economics*, 12(5), 855-866.

Giuliani, E., Pietrobelli, C. & Rabellotti, R. (2005) Upgrading in global value chains: Lessons from latin american clusters. *World Development*, 33(4), 549-573.

Goldberg, P. K., Khandelwal, A., Pavcnik, N. & Topalova, P. (2010a) Imported intermediate inputs and domestic product growth: Evidence from india. *The Quarterly Journal of Economics*, 125(4), 1727-1767.

Goldberg, P. K., Khandelwal, A., Pavcnik, N. & Topalova, P. (2010b) Multiproduct firms and product turnover in the developing world: Evidence from india. *The Review of Economics and Statistics*, 92(4), 1042-1049.

Haidar, J. I. (2012) Trade and productivity: Self-selection or learning-by-exporting in india. *Economic Modelling*, 29(5), 1766-1773.

Harding, T. & Javorcik, B. S. (2012) Foreign direct investment and export upgrading. *Review of Economics and Statistics*, 94(4), 964-980.

Harris, R. & Robinson, C. (2003) Foreign ownership and productivity in the united kingdom estimates for u.K. Manufacturing using the ard. *Review of Industrial Organization*, 22, 207-223.

Hausmann, R., Hwang, J. & Rodrik, D. (2007) What you export matters. *Journal of Economic Growth*, 12(1), 1-25.
Helpman, E., Antras, P. & Acemoglu, D. (2007) Contracts and technology adoption. *The American Economic Review*, 97(3), 916-943.
Helpman, E., Melitz, M. & Yeaple, S. (2004) Export versus fdi with heterogeneous firms. *The American Economic Review*, 94(1), 300-316.
Hirano, K., Imbens, G. W. & Ridder, G. (2003) Efficient estimation of average treatment effects using the estimated propensity score. *Econometrica*, 71(4), 1161-1189.
Humphrey, J. & Schmitz, H. (2002) How does insertion in global value chains affect upgrading in industrial clusters? *Regional Studies*, 36(9), 1017-1027.
Imbens, G. W. & Rubin, D. B. (2015) *Causal inference for statistics, social, and biomedical sciences: An introduction*. Cambridge: Cambridge University Press.
Javorcik, B. S. & Arnold, J. M. (2009) Gifted kids or pushy parents? Foreign direct investment and plant productivity in indonesia. *Journal of international Economics*, 79(1), 42-53.
Kumar, N. & Aggarwal, A. (2005) Liberalization, outward orientation and in-house r&d activity of multinational and local firms: A quantitative exploration for indian manufacturing. *Research Policy*, 34(4), 441.
Kummritz, V., Taglioni, D. & Winkler, D. (2017) Economic upgrading through global value chain participation: Which policies increase the value added gains?
Lall, S. (2002) Linking fdi and technology development for capacity building and strategic competitiveness. *Transnational Corporations*, 11(3), 39-88.
Lancheros, S. (2016) Exports, outward fdi and technology upgrading: Firm level evidence from india. *The Journal of Development Studies*, 52(10), 1415-1430.
Lechner, M. (2002) Program heterogeneity and propensity score matching: An application to the evaluation of active labor market policies. *The Review of Economics and Statistics*, 84(2), 205-220.
Levinsohn, J. & Petrin, A. (2003) Estimating production functions using inputs to control for unobservables. *The Review of Economic Studies*, 70(2), 317-341.
Lileeva, A. & Trefler, D. (2010) Improved access to foreign markets raises plant-level productivity… for some plants. *Quarterly Journal of Economics*, 125(3), 1051.
Melitz, M. (2003) The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6), 1695-1725.
Meyer, B. (2016) Product Mix and Foreign Ownership: Evidence from Indias Investment Liberalization. Mimeo.
Morrison, A., Pietrobelli, C. & Rabellotti, R. (2008) Global value chains and technological capabilities: A framework to study industrial innovation in developing countries. *Oxford Development Studies*, 36(1), 39-58.
Mundlak, Y. (1978) On the pooling of time series and cross section data. *Econometrica*, 46(1), 69-85.
Pietrobelli, C. & Rabellotti, R. (2011) Global value chains meet innovation systems: Are there learning opportunities for developing countries? *World Development*, 39(7), 1261-1269.
Pradhan, J. P. (2002) Liberalization, firm size and r&d performance: A firm level study of indian pharmaceutical industry. *Journal of Indian School of Political Economy*, 14(4), 647-666.
Purkayastha, S., Manolova, T. S. & Edelman, L. F. (2016) Business group effects on the r&d intensity-internationalization relationship: Empirical evidence from india. *Journal of World Business*.
Raff, H., Stähler, F. & Van Long, N. (2011) Innovation and trade with heterogeneous firms. *Journal of international Economics*, 84(2), 149-159.
Salomon, R. M. & Shaver, J. M. (2005) Learning by exporting: New insights from examining firm innovation. *Journal of Economics &Management Strategy*, 14(2), 431–460.
Singh, D. A. & Gaur, A. S. (2013) Governance structure, innovation and internationalization: Evidence from india. *Journal of International Management*, 19(3), 300-309.

Van Biesebroeck, J. (2005) Exporting raises productivity in sub-saharan african manufacturing firms. *Journal of International Economics*, 67(2), 373-391.

Veugelers, R., Barbiero, F. & Blanga-Gubbay, M. (2013) Meeting the manufacturing firms involved in gvcs, in Veugelers, R. (ed), *Manufacturing europe's future*. Brüssel: Bruegel.

Wagner, J. (2007) Exports and productivity: A survey of the evidence from firm-level data. *The World Economy*, 30(1), 60-82.

Wooldridge, J. M. (2007) Inverse probability weighted estimation for general missing data problems. *Journal of Econometrics*, 141(2), 1281-1301.

Wooldridge, J. M. (2010) *Econometric analysis of cross section and pandel data*. Cambridge, Massachusetts, London, England: MIT press.

8. Appendix

Table 7: Sectoral distribution of firms across GVC modes, 1990-2013 (in percent)

Sector		No	Limited	Low	Inter-mediate	High	Total number of firms
Food	10	47.73	26.53	21.91	3.52	0.31	1 278
Beverages	11	45.28	32.88	21.02	0.81	0.00	371
Tobacco	12	38.85	44.60	13.67	2.88	0.00	139
Textiles	13	35.00	37.06	21.47	5.59	0.96	1 360
Wearing apparel	14	21.91	28.98	34.98	10.60	3.18	283
Leather	15	15.58	22.08	37.66	19.48	5.19	154
Wood	16	31.43	28.57	34.29	5.71	0.00	140
Paper	17	23.21	41.33	29.85	5.61	0.00	392
Printing	18	45.14	32.00	22.86	0.00	0.00	175
Coke & Petroleum	19	23.94	18.31	35.92	19.72	2.11	142
Chemicals	20	20.52	33.25	32.89	12.19	1.15	1 657
Pharmaceuticals	21	19.32	35.94	27.56	13.78	3.41	704
Rubber & Plastic	22	26.08	37.90	26.34	7.66	2.02	744
Non-metallic mineral products	23	28.99	27.95	32.51	9.52	1.04	483
Basic metals	24	35.55	32.30	24.98	6.59	0.58	1 381
Fabricated products	25	30.00	42.45	23.27	3.88	0.41	490
Computer	26	9.21	24.03	42.19	19.76	4.81	749
Electrical equipment	27	18.60	39.91	29.04	10.73	1.72	699
Other machinery	28	11.69	43.73	34.23	9.99	0.37	821
Automobiles	29	2.22	13.33	55.56	28.89	0.00	45
Other transport equipment	30	12.46	44.52	32.06	10.63	0.33	602
Furniture	31	11.63	55.81	11.63	20.93	0.00	43
Other manufacturing	32	12.08	20.07	29.18	28.81	9.85	538

Note: The given percentages of firms and the total numbers of firms is calculated without explicitly taking the time dimension into account. Note, that though the total number of firms is 11,917, the sum of the number of firms here is higher since firms can switch sectors and are therefore taken into account multiple times here.

Table A 1: Examples of industries, sectors and products

NIC			Description
22	Sector		Manufacture of rubber and plastic products
2211	Industry		Manufacture of rubber tyres and tubes, retreading and rebuilding
	11031001000000	Products	Rubber tyres and tubes for motor vehicles, motorcycles.
	11031001020000		Bus and lorry tyres
	11031001030000		Aero tyres
	11031001040101		Scooter 2 wheeler tyres
	11031001040102		Scooter 3 wheeler tyres
	11031001050000		Cycle tyres
	…		

2219	Industry		Manufacture of other rubber products
	11030801000000	Products	Hoses, tubes and pipes of vulcanised rubber
	11030801010000		Vacuum brake hoses
	11030801050000		Fire fighting hose
	11031401000000		Rubber gloves
	11031402000000		Rubber aprons
	11039901000000		Rubber balloons
	…		
2220	Industry		Manufacture of plastic products
	11020903020000	Products	Synthetic leather baggage
	14160199060000		Cassettes
	14160199060100		Audio cassettes
	14160199060700		Compact Discs
	…		

Note: Only a subset of the available products are listed for the respective industries in the manufacture of rubber and plastic products sector. For NIC 2211 there are a total of 37 products, for NIC 2219 there are a total of 60 products and for NIC 2220 there are a total of 82 products. The five-digit product classification comprises the first ten numbers of the product code.

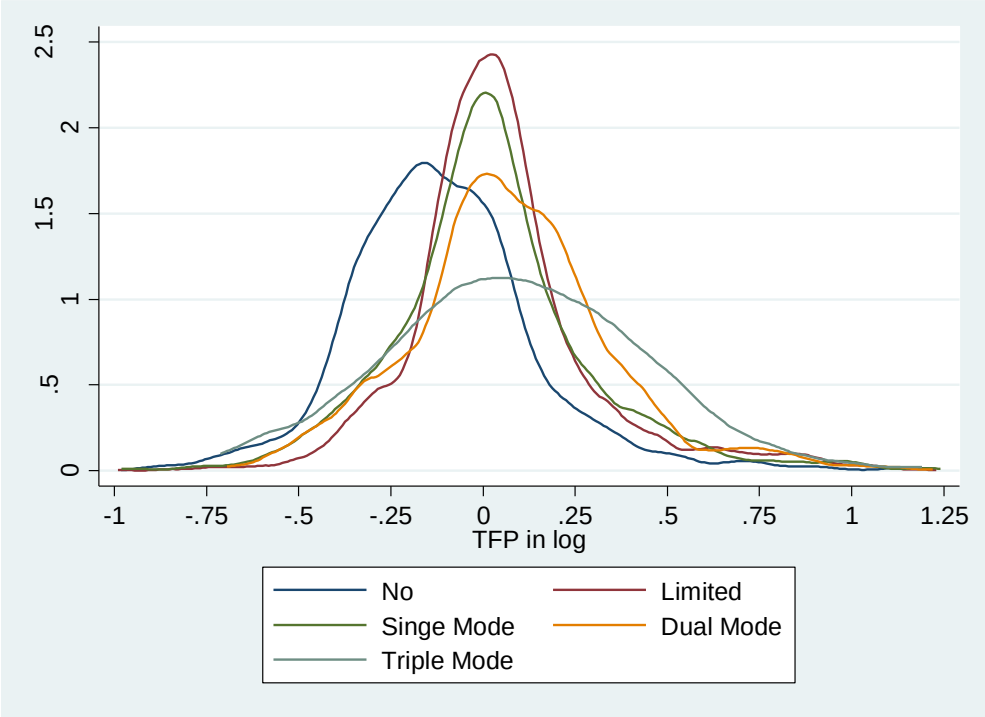
Table A 2: Product coproduction within the triple mode, 1989-2013

Sector		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Food	10	135	6	1	2	1	2	0	1	0	0	54	11	1	1	0	0	2	1	7	0	0	0	0
Beverages	11	6	4	0	0	0	0	0	0	0	0	6	5	0	0	0	0	0	0	0	0	0	0	0
Tobacco	12	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Textiles	13	2	0	0	24	4	0	0	1	0	0	10	3	1	0	1	0	3	1	3	0	0	0	0
Wearing apparel	14	1	0	0	4	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Leather	15	2	0	0	0	1	6	0	0	0	0	5	0	0	0	0	0	1	0	1	0	0	0	0
Wood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper	17	1	0	2	1	0	0	0	5	0	0	5	3	2	0	1	2	3	1	3	0	0	0	0
Printing	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coke & Petroleum	19	0	0	0	0	0	0	0	0	0	1	2	0	0	0	2	0	0	1	0	0	0	0	0
Chemicals	20	54	6	0	10	2	5	0	5	0	2	275	95	8	3	10	3	12	6	14	0	0	0	3
Pharmaceuticals	21	11	5	0	3	0	0	0	3	0	0	95	176	2	4	1	1	8	1	1	0	0	0	5
Rubber & Plastic	22	1	0	0	1	0	0	0	2	0	0	8	2	27	1	2	2	4	2	4	0	5	0	0
Non-metallic mineral products	23	1	0	0	0	0	0	0	0	0	0	3	4	1	7	1	0	5	4	2	0	1	0	0
Basic metals	24	0	0	0	1	0	0	0	1	0	2	10	1	2	1	47	15	8	10	23	1	10	0	0
Fabricated products	25	0	0	0	0	0	0	0	2	0	0	3	1	2	0	15	14	3	7	19	0	12	1	0
Computer	26	2	0	0	3	0	1	0	3	0	0	12	8	4	5	8	3	73	64	27	0	7	0	1
Electrical equipment	27	1	0	0	1	0	0	0	1	0	1	6	1	2	4	10	7	64	71	36	0	9	0	1
Other machinery	28	7	0	0	3	0	1	0	3	0	0	14	1	4	2	23	19	27	36	127	2	17	1	1
Automobiles	29	0		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	2	0	0
Other transport equipment	30	0	0	0	0	0	0	0	0	0	0	0	0	5	1	10	12	7	9	17	2	6	0	0
Furniture	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Other manufacturing	32	0	0	0	0	0	0	0	0	0	0	3	5	0	0	0	0	1	1	1	0	0	0	1

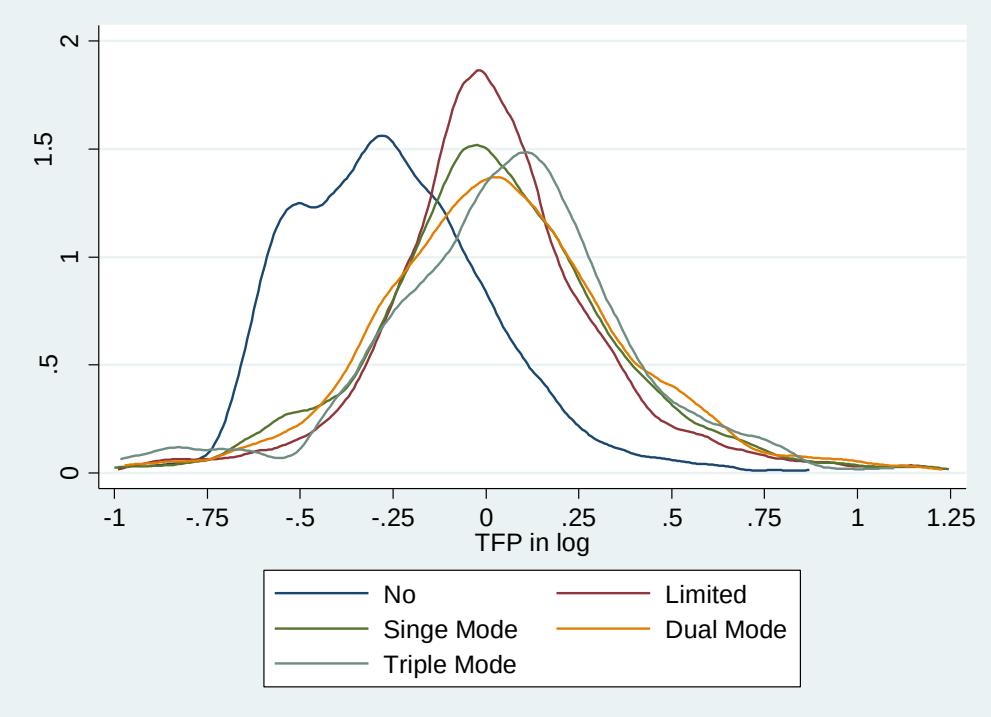
Notes: Table summarizes co-production at level five of the CMIE product classification across multiple-product firms. Each cell contains a count (in 100s) of the average number of triple moders observed producing at least two products in the noted first tier product sector from 1989 to 2013. Firms with more than two products may be counted more than once in each cell. Dark and light blue shading indicate statistically significantly higher and lower co-production at the 1 percent level, respectively, than is implied by a null hypothesis of random co-production. The absence of shading indicates the absence of statistically significant differences from this null hypothesis. Dark orange and light orange shading indicate further statistical significantly higher and lower co-production at the 1 percent level of firms in the triple mode compared to domestic firms. Thus, the orange shading on top of the blue indicates whether the non-random co-production behavior is statistically more or less pronounced by triple moders. Adapted from Meyer (2016)

Figure A 1: Total Factor Productivity density and different modes of internationalization

Panel (a): Apparel and Textiles[51]



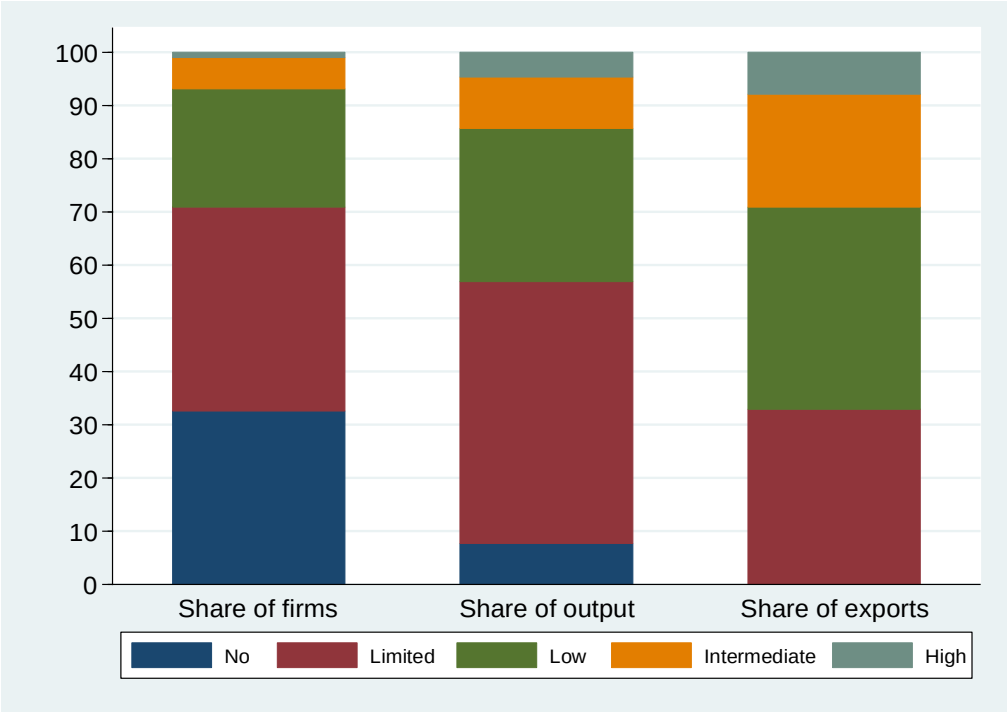
Panel (b): Electronics[52]



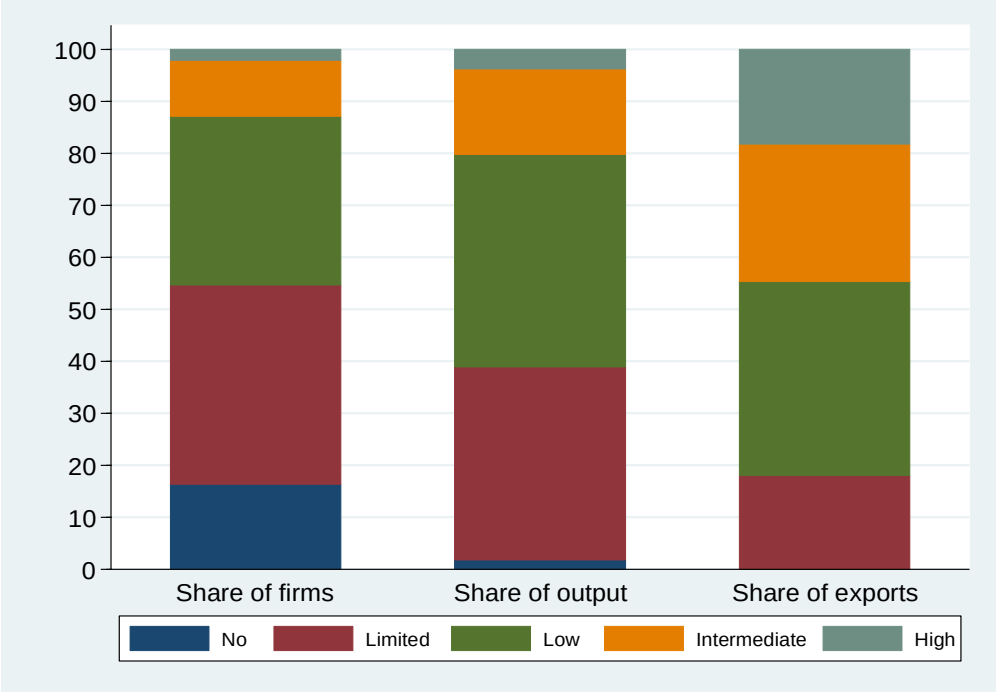
[51] Apparel and Textiles comprise the sector categories 13, 14 and 15 (according to 2-digit NIC classification).
[52] Electronics comprise the sector categories 26 and 27 (according to 2-digit NIC classification).

Figure A 2: Distribution of firms, output and exports according to different modes of integration into Global Value Chains

Panel (a): Apparel and Textiles[53]



Panel (b): Electronics[54]



[53] Apparel and Textiles comprise the sector categories 13, 14 and 15 (according to 2-digit NIC classification).
[54] Electronics comprise the sector categories 26 and 27 (according to 2-digit NIC classification).

Table A 3: Sector specific odds ratio of engaging in GVCs with different modes: Textiles and Apparel and Electronics[55]

	(1) Textiles	(2) Electronics	(3) Textiles	(4) Electronics
Tfp	1.134	2.615***	1.135	2.687***
	(0.176)	(0.478)	(0.176)	(0.453)
Size	3.251***	2.262***	3.251***	2.224***
	(0.187)	(0.135)	(0.187)	(0.140)
Skills	0.966	0.987	0.965	1.005
	(0.0336)	(0.0399)	(0.0339)	(0.0473)
Financial Leverage	0.990	1.001***	0.990	1.001***
	(0.0157)	(0.000327)	(0.0155)	(0.000325)
Age	1.002	1.002	1.002	1.001
	(0.00274)	(0.00408)	(0.00275)	(0.00418)
Special Economic Zones			1.076	0.811
			(0.146)	(0.164)
Industry Agglomeration			4.634**	2.665
			(3.008)	(2.454)
Export Advantage			0.937	0.999
			(0.279)	(0.347)
Fixed Effects	Firm Year Industry	Firm Year Industry	Firm Year Industry	Firm Year Industry
Number of Observation	8,902	5,883	8,902	5,241
Log Likelihood	-10242	-6763	-10237	-5997
Pseudo R^2	0.174	0.133	0.174	0.130

Notes: Pooled estimation. Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

[55] Apparel and Textiles comprise the sector categories 13, 14 and 15 (according to 2-digit NIC classification). Electronics comprise the sector categories 26 and 27 (according to 2-digit NIC classification).

Table A 4: Determinants of RnD Expenditures depending on the depth of GVC participation

	Increase in RnD Expenditures (0/1)					RnD Expenditures				
	No	Limited	Low	Intermediate	High	No	Limited	Low	Intermediate	High
Age	0.0002*	0.0001	0.0005**	0.0006	0.0016	-0.0005***	-0.0014***	-0.0009***	-0.0012***	-0.0027
	(0.0001)	(0.0002)	(0.0002)	(0.0004)	(0.0018)	(0.0001)	(0.0002)	(0.0002)	(0.0004)	(0.0018)
Output	0.0123***	0.0082**	0.0215***	0.0141**	0.0258*	0.0109***	0.0605***	0.0473***	0.0277***	0.0624***
	(0.0025)	(0.0034)	(0.0035)	(0.0069)	(0.0156)	(0.0037)	(0.0040)	(0.0042)	(0.0081)	(0.0209)
Leverage	-0.0021	0.0040	-0.0019	0.0093	-0.0038	0.0183***	-0.0038	-0.0039	-0.0173**	-0.0317*
	(0.0031)	(0.0079)	(0.0084)	(0.0178)	(0.0287)	(0.0037)	(0.0042)	(0.0050)	(0.0077)	(0.0186)
Productivity	0.0175	0.0294	0.0395**	0.1095***	0.2477***	0.0939***	0.1000***	0.0802***	0.1647***	0.4112***
	(0.0160)	(0.0188)	(0.0180)	(0.0360)	(0.0881)	(0.0183)	(0.0164)	(0.0150)	(0.0263)	(0.0841)
Skill	-0.0012	0.0134***	0.0185***	0.0181*	0.0589***	0.0014	0.0289***	0.0468***	0.0697***	0.0096
	(0.0017)	(0.0047)	(0.0052)	(0.0107)	(0.0217)	(0.0019)	(0.0033)	(0.0035)	(0.0078)	(0.0204)
GVC experience	0.0012	0.0306***	0.0361***	0.0179***	0.0172***	-0.0006	0.0009*	0.0013*	0.0040***	0.0024***
	(0.0011)	(0.0005)	(0.0005)	(0.0012)	(0.0032)	(0.0006)	(0.0006)	(0.0007)	(0.0014)	(0.0009)
SEZ	-0.0028	-0.0214***	-0.0409***	-0.0427***	-0.0770***	-0.0079	0.0034	0.0013	-0.0107	0.0107
	(0.0027)	(0.0059)	(0.0066)	(0.0129)	(0.0293)	(0.0056)	(0.0089)	(0.0097)	(0.0176)	(0.0470)
Export Advantage	-0.0436*	-0.0444	0.0238	0.0215	0.0473	-0.1115**	0.0742	-0.1129	-0.0539	-0.4027
	(0.0255)	(0.0516)	(0.0591)	(0.0938)	(0.2013)	(0.0511)	(0.0646)	(0.0770)	(0.1189)	(0.3251)
Competition	0.1092*	-0.2063	-0.1512	0.2778	-1.4554	0.2998**	-0.2737	-0.1320	0.3548	0.5914
	(0.0613)	(0.1496)	(0.1850)	(0.3642)	(0.9963)	(0.1209)	(0.1802)	(0.2126)	(0.4171)	(1.1906)
Market Share	0.0730**	0.1266***	0.0176	0.0414	-0.3086	0.1872***	0.0914*	-0.0453	-0.1497	-0.1785
	(0.0335)	(0.0485)	(0.0484)	(0.0759)	(0.1937)	(0.0515)	(0.0531)	(0.0592)	(0.1753)	(0.2466)
Sector Skills	0.0682	0.4566**	0.4116*	1.0450**	1.0604*	-0.0216	0.2948	-0.2222	-0.5007	-1.5032
	(0.0906)	(0.1945)	(0.2420)	(0.4402)	(0.6005)	(0.2136)	(0.2725)	(0.3316)	(0.5607)	(1.6039)
Constant	0.0363**	0.1762***	0.2518***	0.4176***	0.1381	-0.0296	0.0192	0.1185**	0.2775**	0.0539
	(0.0163)	(0.0247)	(0.0255)	(0.0577)	(0.1457)	(0.0357)	(0.0418)	(0.0495)	(0.1124)	(0.4323)
Observations	57,136	57,136	57,136	57,136	57,136	57,135	57,135	57,135	57,135	57,135

Note: Estimation of equation (2) used to obtain the predicted innovation outcome weighted by inverse propensity scores. Time, industry and country fixed effects (Mundlak-Chamberlain device for bivariate innovation outcome variables) are used in each estimation. Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table A 5: Determinants of Process Innovation depending on the depth of GVC participation

	Engaging in Process Innovation (0/1)					Expenditures on Process Innovation				
	No	Limited	Low	Intermediate	High	No	Limited	Low	Intermediate	High
Age	-0.0005***	-0.0015***	-0.0010***	-0.0016***	-0.0033*	-0.0002***	-0.0009***	-0.0006*	-0.0013	-0.0089***
	(0.0001)	(0.0002)	(0.0002)	(0.0004)	(0.0018)	(0.0001)	(0.0002)	(0.0003)	(0.0008)	(0.0028)
Output	0.0089**	0.0575***	0.0430***	0.0216***	0.0691***	0.0042	0.1676***	0.2123***	0.2899***	0.2957***
	(0.0036)	(0.0040)	(0.0042)	(0.0081)	(0.0207)	(0.0026)	(0.0056)	(0.0068)	(0.0146)	(0.0371)
Leverage	-0.0090	-0.0069	-0.0333***	-0.0286	-0.0682*	-0.0023	-0.0075	0.0516***	0.0107	0.0456
	(0.0059)	(0.0094)	(0.0104)	(0.0192)	(0.0364)	(0.0028)	(0.0112)	(0.0183)	(0.0343)	(0.0603)
Productivity	0.0228	0.0827***	0.0846***	0.1100**	0.3512***	0.0539***	0.0676**	0.1794***	0.2792***	0.2787***
	(0.0246)	(0.0243)	(0.0259)	(0.0488)	(0.1298)	(0.0193)	(0.0301)	(0.0359)	(0.0866)	(0.0823)
Skill	-0.0049	-0.0238***	-0.0239***	-0.0233*	-0.0351	-0.0030	-0.0280***	-0.0179*	0.0138	0.0027
	(0.0036)	(0.0062)	(0.0069)	(0.0141)	(0.0305)	(0.0022)	(0.0077)	(0.0097)	(0.0215)	(0.0515)
GVC experience	-0.0008	0.0171***	0.0312***	0.0401***	0.0366**	-0.0003	0.0019***	0.0026***	0.0040*	0.0117**
	(0.0007)	(0.0005)	(0.0006)	(0.0013)	(0.0016)	(0.0003)	(0.0006)	(0.0008)	(0.0021)	(0.0055)
SEZ	-0.0851*	0.0028	-0.0091	-0.0312	-0.0152	-0.0271***	0.0015	-0.0105	-0.0048	-0.0324
	(0.0046)	(0.0074)	(0.0080)	(0.0246)	(0.0377)	(0.0020)	(0.0082)	(0.0113)	(0.0229)	(0.0517)
Export Advantage	-0.0249	0.0801	-0.0123	-0.0288	-0.3174	-0.0278*	0.0893	0.1358	0.1006	0.1434
	(0.0463)	(0.0611)	(0.0719)	(0.1098)	(0.3192)	(0.0161)	(0.0571)	(0.0906)	(0.1523)	(0.4428)
Competition	0.2873**	0.2187	0.2362	0.3209	0.3597	0.1391**	0.5211**	1.2378***	4.1947***	1.2959**
	(0.1215)	(0.1802)	(0.2122)	(0.4179)	(0.4987)	(0.0606)	(0.2068)	(0.3071)	(0.7566)	(0.6433)
Market Share	-0.1616**	0.1672***	0.0695	-0.0634	-0.2403	0.0250	0.4022***	0.6153***	0.2154*	1.6751**
	(0.0766)	(0.0516)	(0.0529)	(0.0579)	(0.2468)	(0.0345)	(0.0812)	(0.1062)	(0.1144)	(0.7085)
Sector Skills	-0.5198***	-0.3350	-0.4186	-0.6909*	-1.9644***	-0.2056***	-0.8703***	-2.4747***	-2.6814***	-1.5885
	(0.1582)	(0.2263)	(0.2796)	(0.3962)	(0.5516)	(0.0637)	(0.2372)	(0.3384)	(0.7303)	(1.8479)
Constant	-0.0349	0.0537*	0.1922***	0.2043***	-0.2321	-0.0662***	-0.1188***	0.0183	-0.0420	0.1846
	(0.0231)	(0.0300)	(0.0312)	(0.0679)	(0.1811)	(0.0180)	(0.0318)	(0.0425)	(0.1065)	(0.2638)
Observations	57,136	57,136	57,136	57,136	57,136	57,135	57,135	57,135	57,135	57,135

Note: Estimation of equation (2) used to obtain the predicted innovation outcome weighted by inverse propensity scores. Time, industry and country fixed effects (Mundlak-Chamberlain device for bivariate innovation outcome variables) are used in each estimation. Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table A 6: Determinants of Product Innovation and Product Deconstruction depending on the depth of GVC participation

	Engaging in Product Innovation (0/1)					Engaging in Product Deconstruction (0/1)				
	No	Limited	Low	Intermediate	High	No	Limited	Low	Intermediate	High
Age	-0.0006***	0.0002	0.0003	0.0001	-0.0006	0.0005**	0.0009***	0.0014***	0.0014***	0.0030
	(0.0002)	(0.0002)	(0.0002)	(0.0004)	(0.0015)	(0.0002)	(0.0002)	(0.0002)	(0.0004)	(0.0019)
Output	0.0205***	0.0479***	0.0318***	0.0212***	0.0140**	0.0251***	0.0356***	0.0198***	0.0119	-0.0229
	(0.0055)	(0.0043)	(0.0041)	(0.0071)	(0.0071)	(0.0069)	(0.0049)	(0.0047)	(0.0082)	(0.0201)
Leverage	-0.0018	-0.0019	0.0004	0.0165**	-0.0088	0.0032	0.0027	0.0144***	0.0388***	0.0366*
	(0.0043)	(0.0040)	(0.0047)	(0.0079)	(0.0167)	(0.0057)	(0.0047)	(0.0054)	(0.0089)	(0.0211)
Productivity	0.1588**	0.1202***	0.1618***	0.1101***	0.1077***	-0.0536	-0.1851***	-0.2389***	-0.1682***	0.1632
	(0.0678)	(0.0514)	(0.0489)	(0.0359)	(0.0376)	(0.0793)	(0.0570)	(0.0480)	(0.0433)	(0.4340)
Skill	0.0141***	0.0198***	0.0095**	0.0124*	0.0137**	0.0001	-0.0071*	-0.0028	0.0049	0.0069
	(0.0032)	(0.0037)	(0.0037)	(0.0071)	(0.0059)	(0.0041)	(0.0043)	(0.0043)	(0.0084)	(0.0182)
GVC experience	-0.0012	0.0028***	0.0026***	0.0026***	0.0025***	0.0065***	0.0010	0.0004	0.0015	0.0020
	(0.0010)	(0.0006)	(0.0006)	(0.0012)	(0.0013)	(0.0014)	(0.0007)	(0.0007)	(0.0014)	(0.0039)
Productivity^2	-0.0515**	-0.0087	-0.0138	-0.0078	-0.0805	-0.0125	0.0464**	0.0655***	-0.0019	-0.0318
	(0.0224)	(0.0166)	(0.0152)	(0.0048)	(0.1365)	(0.0250)	(0.0182)	(0.0141)	(0.0069)	(0.1531)
SEZ	-0.0054	-0.0031	-0.0026	-0.0054	-0.0106	0.0072	0.0536***	0.0722***	0.0815***	0.1201***
	(0.0070)	(0.0070)	(0.0072)	(0.0121)	(0.0300)	(0.0095)	(0.0085)	(0.0086)	(0.0142)	(0.0362)
Export Advantage	0.0082	0.0136	-0.0488	-0.0249	0.0321	-0.0228	-0.0227	-0.0332	-0.0378	-0.0736
	(0.0368)	(0.0317)	(0.0309)	(0.0439)	(0.0867)	(0.0475)	(0.0368)	(0.0368)	(0.0517)	(0.0982)
Competition	-0.0167	0.0249	0.1440	0.2670	-0.4828	0.1030	-0.0695	-0.0507	0.3374	-0.7657
	(0.1502)	(0.1430)	(0.1502)	(0.2593)	(0.6551)	(0.1896)	(0.1647)	(0.1764)	(0.3034)	(0.7719)
Market Share	0.0864	-0.0103	0.0063	-0.0095	-0.0808	0.1099	-0.0409	0.0354	0.0222	0.1173
	(0.0925)	(0.0426)	(0.0415)	(0.0595)	(0.2482)	(0.0991)	(0.0482)	(0.0471)	(0.0726)	(0.2435)
Sector Skills	0.4794***	0.3287**	0.4180**	0.2144**	0.2020	0.1828	0.0902	0.2642	0.2619	1.2930
	(0.1545)	(0.1502)	(0.1664)	(0.1081)	(0.1648)	(0.2153)	(0.1743)	(0.1915)	(0.3172)	(0.8019)
Constant	0.0561	0.0738*	0.1731***	0.1820***	0.1514	0.4536***	0.4295***	0.4960***	0.3385***	0.1437
	(0.0480)	(0.0433)	(0.0429)	(0.0562)	(0.2495)	(0.0582)	(0.0492)	(0.0457)	(0.0665)	(0.2919)
Observations	61,885	61,885	61,885	61,885	61,885	61,885	61,885	61,885	61,885	61,885

Note: Estimation of equation (2) used to obtain the predicted innovation outcome weighted by inverse propensity scores. The additional squared productivity term captures the cannibalization effect on other products typically associated with the introduction of a new product. Time, industry and country fixed effects (Mundlak-Chamberlain device for bivariate innovation outcome variables) are used in each estimation. Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table A 7: Determinants of the number of products depending on the depth of GVC participation

	Product Upgrading				
	No	Limited	Low	Intermediate	High
Age	-0.0006**	0.0023***	0.0059***	0.0054***	0.0064**
	(0.0003)	(0.0003)	(0.0003)	(0.0006)	(0.0025)
Output	0.1616***	0.1408***	0.1182***	0.0595***	0.1142***
	(0.0099)	(0.0069)	(0.0069)	(0.0107)	(0.0290)
Leverage	0.0080	-0.0030	0.0110	-0.0136	-0.0129
	(0.0084)	(0.0070)	(0.0078)	(0.0116)	(0.0327)
Productivity	0.2578**	0.1931***	0.1993***	0.1504***	-0.2061
	(0.1167)	(0.0734)	(0.0793)	(0.0533)	(0.5974)
Skill	0.0004	0.0615***	0.0887***	0.1288***	0.0946***
	(0.0057)	(0.0063)	(0.0063)	(0.0111)	(0.0237)
GVC experience	0.0017	0.0032***	0.0031***	0.0155***	0.0122**
	(0.0019)	(0.0010)	(0.0010)	(0.0018)	(0.0051)
Productivity^2	-0.1224***	-0.1314***	-0.1221***	-0.1028***	0.0869***
	(0.0370)	(0.0220)	(0.0243)	(0.0072)	(0.0204)
SEZ	-0.0105	-0.0370***	-0.0518***	-0.1192***	-0.0582***
	(0.0137)	(0.0120)	(0.0119)	(0.0183)	(0.0170)
Export Advantage	-0.2414***	-0.0622	-0.0807	-0.0870	0.1216
	(0.0724)	(0.0530)	(0.0515)	(0.0705)	(0.1420)
Competition	-1.2030***	-1.5941***	-2.0801***	-2.7850***	-1.9381*
	(0.2662)	(0.2299)	(0.2401)	(0.4021)	(1.0356)
Market Share	0.9632***	0.2820***	0.1989***	0.0034	-0.5106
	(0.1349)	(0.0628)	(0.0676)	(0.0960)	(0.4133)
Sector Skills	1.5523***	1.2946***	1.8014***	0.8770**	0.5976
	(0.3296)	(0.2569)	(0.2741)	(0.4062)	(1.0764)
Constant	0.6968***	0.9683***	1.0303***	1.0948***	0.8308**
	(0.0851)	(0.0682)	(0.0702)	(0.0838)	(0.3939)
Observations	60,063	60,063	60,063	60,063	60,063

Note: Estimation of equation (2) used to obtain the predicted innovation outcome weighted by inverse propensity scores. The additional squared productivity term captures the cannibalization effect on other products typically associated with the introduction of a new product. Time, industry and country fixed effects (Mundlak-Chamberlain device for bivariate innovation outcome variables) are used in each estimation. Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table A 8: Determinants of Product Upgrading depending on the depth of GVC participation

	Product Upgrading				
	No	Limited	Low	Intermediate	High
Age	0.0006**	0.0002	0.0004	0.0008	0.0014
	(0.0002)	(0.0002)	(0.0003)	(0.0005)	(0.0020)
Output	-0.0143***	-0.0043	0.0072	-0.0126	0.0072
	(0.0052)	(0.0067)	(0.0050)	(0.0087)	(0.0213)
Leverage	-0.0371***	-0.0467***	-0.0509***	-0.0108	-0.0021
	(0.0139)	(0.0107)	(0.0127)	(0.0209)	(0.0392)
Productivity	-0.0185	-0.0140	-0.0135	0.0682	0.0383
	(0.0386)	(0.0304)	(0.0278)	(0.0477)	(0.1196)
Skill	0.0124	0.0649***	0.0612***	0.0558***	0.1189***
	(0.0078)	(0.0082)	(0.0085)	(0.0155)	(0.0316)
GVC experience	-0.0008	0.0013*	0.0034***	0.0057***	0.0031
	(0.0013)	(0.0007)	(0.0008)	(0.0014)	(0.0039)
SEZ	-0.1138***	-0.1023***	-0.0906***	-0.0871***	-0.1928***
	(0.0096)	(0.0091)	(0.0092)	(0.0155)	(0.0384)
Export Advantage	0.1876****	0. 2417**	0.2609***	0.2463***	0.4252***
	(0.0770)	(0.0992)	(0.0828)	(0.0559)	(0.1279)
Competition	-0.0195	-0.0718	-0.0777	0.0794	-0.2647
	(0.2695)	(0.2373)	(0.2579)	(0.4502)	(1.2791)
Market Share	0.0255	-0.0820	-0.0263	0.0208	-0.3541
	(0.1841)	(0.0541)	(0.0563)	(0.0804)	(0.2385)
Sector Skills	1.1070***	0.8160***	0.8699***	0.9499*	1.4163
	(0.3744)	(0.2915)	(0.3341)	(0.5660)	(1.4532)
Constant	0.3810***	0.5021***	0.4802***	0.6068***	0.6902***
	(0.0439)	(0.0400)	(0.0387)	(0.0763)	(0.1918)
Observations	57,136	57,136	57,136	57,136	57,136

Note: Estimation of equation (2) used to obtain the predicted innovation outcome weighted by inverse propensity scores. Time, industry and country fixed effects (Mundlak-Chamberlain device for bivariate innovation outcome variables) are used in each estimation. Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table A 9: Determinants of Functional Upgrading depending on the depth of GVC participation

	Functional Upgrading				
	No	Limited	Low	Intermediate	High
Age	0.0003	0.0002	-0.0001	-0.0002	-0.0008
	(0.0002)	(0.0002)	(0.0003)	(0.0005)	(0.0018)
Output	0.0292***	0.0156***	0.0166***	0.0175**	0.0183**
	(0.0066)	(0.0050)	(0.0049)	(0.0086)	(0.0091)
Leverage	0.0043	0.0072	0.0053	0.0028	0.0046
	(0.0061)	(0.0051)	(0.0057)	(0.0091)	(0.0224)
Productivity	-0.0854***	0.0083	0.0026	0.0022	0.0309
	(0.0259)	(0.0181)	(0.0155)	(0.0267)	(0.0896)
Skill	0.0121***	0.0166***	0.0146***	0.0108	0.0208
	(0.0042)	(0.0044)	(0.0045)	(0.0088)	(0.0189)
GVC experience	0.0005	-0.0006	-0.0009	0.0261***	0.0253***
	(0.0015)	(0.0007)	(0.0008)	(0.0014)	(0.0009)
SEZ	-0.0021	0.0044	-0.0135	-0.0096	-0.0115
	(0.0100)	(0.0089)	(0.0090)	(0.0148)	(0.0376)
Export Advantage	0.0009	0.1137***	0.2481***	0.1982***	0.3342***
	(0.0518)	(0.0387)	(0.0384)	(0.0540)	(0.1045)
Competition	0.3387*	0.3011*	1.4097***	1.3401***	2.3662***
	(0.1958)	(0.1705)	(0.1821)	(0.3114)	(0.8153)
Market Share	-0.4780***	-0.0669	-0.0212	-0.0590	-0.2876
	(0.1793)	(0.0538)	(0.0568)	(0.0821)	(0.2631)
Sector Skills	1.6068***	0.6274***	0.6710***	0.3134	-0.4852
	(0.2477)	(0.1913)	(0.2041)	(0.3389)	(0.8096)
Constant	0.5422***	0.4547***	0.4665***	0.4867***	0.5897***
	(0.0376)	(0.0344)	(0.0337)	(0.0627)	(0.1350)
Observations	57,136	57,136	57,136	57,136	57,136

Note: Estimation of equation (2) used to obtain the predicted innovation outcome weighted by inverse propensity scores. Time, industry and country fixed effects (Mundlak-Chamberlain device for bivariate innovation outcome variables) are used in each estimation. Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table A 10: Determinants of Intersectoral Upgrading depending on the depth of GVC participation

	Intersectoral Upgrading				
	No	Limited	Low	Intermediate	High
Age	0.0000	0.0002	0.0002*	0.0009***	0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0007)
Output	-0.0028	-0.0040*	0.0041**	-0.0044***	-0.0115**
	(0.0026)	(0.0022)	(0.0019)	(0.0012)	(0.0046)
Leverage	-0.0042**	-0.0066***	-0.0011	-0.0035	-0.0018
	(0.0017)	(0.0016)	(0.0023)	(0.0028)	(0.0068)
Productivity	0.0073	0.0070	-0.0039	-0.0027	0.0729
	(0.0081)	(0.0084)	(0.0062)	(0.0083)	(0.0508)
Skill	-0.0001	0.0021	0.0029	-0.0074**	-0.0146*
	(0.0016)	(0.0018)	(0.0018)	(0.0033)	(0.0078)
GVC experience	0.0000	-0.0003	-0.0002	-0.0014**	-0.0017**
	(0.0005)	(0.0003)	(0.0003)	(0.0006)	(0.0007)
SEZ	-0.0049	0.0039	-0.0052	-0.0096	-0.0264
	(0.0053)	(0.0054)	(0.0060)	(0.0096)	(0.0174)
Export Advantage	-0.4120***	-0.5521***	-0.4612***	-0.4150***	-0.2350
	(0.1192)	(0.0882)	(0.0875)	(0.1130)	(0.2064)
Competition	0.7900***	0.9083***	0.5231***	0.2208	0.6068
	(0.1475)	(0.1277)	(0.1309)	(0.1975)	(0.6272)
Market Share	-0.4628***	-0.1497***	-0.0687*	-0.1280**	0.1296
	(0.1650)	(0.0442)	(0.0392)	(0.0519)	(0.2260)
Sector Skills	0.2198	-0.8475***	-0.6275**	-1.3391***	1.7734***
	(0.3537)	(0.2525)	(0.2973)	(0.4350)	(0.6690)
Constant	-0.0287	0.0866***	0.0457	0.1629**	-0.1182
	(0.0282)	(0.0288)	(0.0302)	(0.0725)	(0.1098)
Observations	55,862	55,862	55,862	55,862	55,862

Note: Estimation of equation (2) used to obtain the predicted innovation outcome weighted by inverse propensity scores. Time, industry and country fixed effects (Mundlak-Chamberlain device for bivariate innovation outcome variables) are used in each estimation. Robust standard errors clustered at the firm level in brackets. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.