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# The Role of Digitalisation in Shaping India's Global Value Chain Participation

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**Abstract:** *This study investigates the role of digital infrastructure in shaping the global value chain (GVC) participation of Indian manufacturing firms. To examine the digitalisation and GVC nexus, a rich, firm-level, unbalanced panel of 4,875 manufacturing firms from the past 2 decades is employed to detail the rising importance of digital infrastructure in the Indian context and then to examine empirically the relationship between digitalisation and GVCs. Employing a logit model, a positive, significant impact of digitalisation is found regarding firms' GVC participation. Further, subsample results highlight that digitalisation promotes integration of small firms and firms from low-technology industries into the GVC. The findings of the analysis are robust to alternate measures of the GVCs.*

**Keywords:** Digitalisation; Indian Manufacturing; Global Value Chains

**JEL Classification:** F14; F15; L86; O14

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# 1. Introduction

Over the past 2 decades, global value chains (GVCs) – a series of stages involved in producing a product or service that is sold to consumers, with each stage adding value, and with at least two stages being produced in different countries (Antràs, 2020) – have experienced an unprecedented rise in the global trade paradigm. According to recent estimates, 85% of global trade can be characterised as trade within the GVC framework (Sampath and Vallejo, 2018). This phenomenon is due to the ability of GVCs to stimulate productivity growth and to provide a myriad of opportunities to internationalise and to form network ties with lead firms (Taglioni and Winkler, 2016; World Bank, 2020). As a result, firms obtain improved access to knowledge, technical know-how, and foreign markets (Ernst and Kim, 2002; Gereffi and Fernandez-Stark, 2011; Gereffi, 1999). Thus, firms from developing countries have been trying to increase their participation in GVCs.

GVCs, however, are not resistant to regional or global shocks. The phenomenon of GVCs peaked prior to the global financial crisis, after which their growth levelled off (World Bank, 2020). Similarly, the onset of the COVID-19 pandemic has brought to forefront the vulnerability of existing GVCs, which points to the need to build a more resilient, robust value chain infrastructure (Miroudot, 2020). Transforming the existing system of GVCs requires improving trade facilitation, where the role of firm digitalisation plays an important role both to integrate and to upgrade a firm in the supply chain (Hoekman and Shepherd, 2015; Taglioni and Winkler, 2016).

Within in this frame of reference, the importance of digitisation originates from its ability to reduce distance and entry costs for firms by facilitating greater ease in communication and access to foreign markets (Cassetta et al., 2020). Further, digitalisation allows firms to develop new commercial relationships with other firms all over the globe, thereby providing firms with an avenue to increase their knowledge of foreign markets, develop marketing and sales strategies, and identify competitors (Bianchi and Mathews, 2016; Freund and Weinhold, 2004). Improved digital infrastructure also enables better connectivity with international suppliers, distribution networks, and customers, providing firms with a foundation

to integrate into GVCs (Marchi, Maria, Gereffi, 2018; Jin, Vonderembse, Ragu-Nathan, Smith, 2014; Jean, Sinkovics, Tamer Cavusgil, 2010; Cardona, Kretschmer, Strobel, 2013).

Digitalisation has important implications for supply chain management, as it provides firms with a repository of real-time data that induce efficient inventory management practices and improved capacity planning (Porter and Heppelmann, 2014; Strange and Zucchella, 2017). Real-time data also enable firms to take preventive measures with respect to machinery involved, reducing disruptions along the supply chain (Bughin, Lund, Manyika, 2015). Digitalisation promotes stronger backward GVC participation, i.e. foreign import content to domestic exports (World Bank, 2020). Similarly, the World Economic Forum noted that organisations with stronger digital infrastructure have tackled COVID-19 pandemic disruptions better than firms with inadequate digital infrastructure (Hedwall, 2020). The World Trade Organization concurred, stating that digital preparedness is an important factor in mitigating supply chain disruptions (WTO, 2020). Various studies have also highlighted that production networks that are flexible have better, more rapid responses to natural disasters (Kimura, Thangavelu, Narjoko, Findlay, 2020).

Given the pivotal role of digitalisation in facilitating global trade as well as dealing with the pandemic, this study examines the implication of digitalisation on the participation and upgrading of Indian manufacturing firms in GVCs. Indian manufacturing firms were chosen, as their participation in GVCs is stimulating productivity growth of the stagnant Indian manufacturing sector. Since the 1980s, the contribution of the manufacturing sector has hovered around 15% of India's gross domestic product (GDP) (Bhattacharjee and Chakrabarti, 2013), much lower than those of newly industrialised Asian economies (Mohanty and Saha, 2019). Indeed, in 2010–2011, India's manufacturing contribution to GDP was 15.8%, compared to 30.0% in China, 36.0% in Thailand, 26.0% in Malaysia, and 22.0% in Singapore (PwC, 2012). However, recent policy initiatives, including Make in India, National Policy for Advanced Manufacturing, Atmanirbhar Bharat,[1] and

[1] The Prime Minister, in his address to the nation on 12 May 2020, highlighted the vision of Self-Reliant India (PIB 2020).

various investments in infrastructure projects worth $1.4 trillion under the National Infrastructure Pipeline, have been aimed at promoting foreign direct investment and integrating the Indian economy more profoundly in the GVC framework (PIB 2019).

The study is organised as follows. Section 2 reviews the literature connecting GVCs and digitalisation. Section 3 documents facts on digitalisation and GVC participation in India. Section 4 details data sources and variable construction. Section 5 explains the methodology used in the empirical analysis. Section 6 presents the empirical results, and Section 7 elucidates the robustness through various subsample analyses. Finally, Section 8 concludes with some policy implications.

## 2. Literature Review

Digitalisation is a multidimensional and rapidly evolving concept that incorporates a multitude of digital technologies, such as the internet, electronic data exchange using e-mail or other online systems, dedicated online platforms and marketplaces, and advanced manufacturing or Industry 4.0.[2]

Nordås and Piermartini (2004) investigated the importance of quality infrastructure on trade performance. Using the gravity model, their study underscored the importance of quality infrastructure in trade performance. Further, based on the automotive, clothing, and textile industries, their study highlighted that telecommunications services are pivotal for export competitiveness in these sectors. Freund and Weinhold (2004) examined the effect of the internet on export growth of 56 countries from 1997 to 1999, finding that a 10% increase in web hosting in a country boosts its export growth by 0.2%. Further, Clarke (2008) found internet access to be a key determinant for exports of small and medium-sized enterprises (SMEs) belonging to low- and middle-income countries from Eastern Europe and Central Asia.

[2] Industry 4.0 is also referred to as smart factory, industrial internet of things, advanced manufacturing, and supply chain 4.0 (Ferrantino and Koten, 2019; Matt and Rauch, 2020; Tjahjono, Esplugues, Ares, Pelaez, 2017)

Similarly, using cross-country firm-level data from 12 European economies, Hagsten and Kotnik (2017) proxied firm information and communications technology (ICT) capacity based on having websites, engaging in online transactions, and counting the employees who have broadband internet access or post-upper secondary ICT education. They found that ICT capability significantly impacts both export participation and export intensity of these SMEs. Ahmad, Ismail, and Hook (2011) examined the impact of ICT infrastructure on Malaysian trade with 36 trading partners during 1980–2008. Employing a gravity model, they found that ICT infrastructure in the form of mobile connectivity and numbers of internet users and personal computers are significant factors, positively influencing bilateral trade between Malaysia and its trading partners. Further, using Chinese firm- and province-level data, Fernandes, Mattoo, Nguyen, and Schiffbauer (2019) reported that access to the internet has a significant, positive impact on Chinese manufacturing firms' exports.

Cassetta, Monarca, Dileo, Di Berardino, and Pini (2020) investigated the relationship between digital technologies and internationalisation of Italian SMEs. They discovered that the use of digital technology embedded in process, as well as organisational, innovation has a positive impact on the export propensity of Italian SMEs. Further, Atasoy (2020) studied the impact of digitalisation on the export sophistication of 61 countries using data from 1995 to 2017, demonstrating that digitalisation aids in export sophistication.

From a broader perspective of Industry 4.0 and its implication for global supply chains, Rahman (2003) highlighted how the internet has become a dynamic medium for interaction between buyers and producers, transforming the traditional supply chain structure. To this end, Rahman elicited survey responses from 140 sample firms, showing that 80% of the firms use the internet for supply chain management of transport, inventory, and purchasing/procurement, which includes communication with vendors, price quotes, and sometimes negotiations with vendors. Porter and Heppelmann (2014), as well as Strange and Zucchella (2017), detailed improved inventory management due to adoption of digital technologies. Bughin, Lund, and Manyika (2015) posited that the adoption of digital technologies

provide firms with real-time data, which enable them to identify any wear and tear of equipment.

Regarding literature that specifically examines the importance of digitalisation from a GVC perspective, Foster and Graham (2017) undertook a qualitative case study of the Rwandan tea sector and highlighted digital infrastructure as a pivotal factor in helping firms integrate into GVCs. In a case study of East African firms, Foster, Graham, Mann, Waema, and Friederici (2018) documented that higher internet connectivity and adoption facilitate greater participation in GVCs. However, they also found that such gains mostly accrue to large firms. Fort (2017), using survey data of United States manufacturing firms for 2002 to 2007, found that firms that incorporate advanced ICT in the form of electronic data exchange, e-mail, and extranet experience increased fragmentation. This econometric analysis highlighted that industries in which production specification can be codified in an electronic format experience a 20% higher increase in fragmentation relative to the mean industry level.

The review of existing literature highlights the dearth of studies that examine the digitalisation and GVC nexus. Systematic evidence is even rarer in the context of Asian economies. To this end, this study attempts to fill this gap by investigating the role of digital infrastructure on the GVC participation of Indian firms.

## 3. Digitalisation and Global Value Chain Participation in India

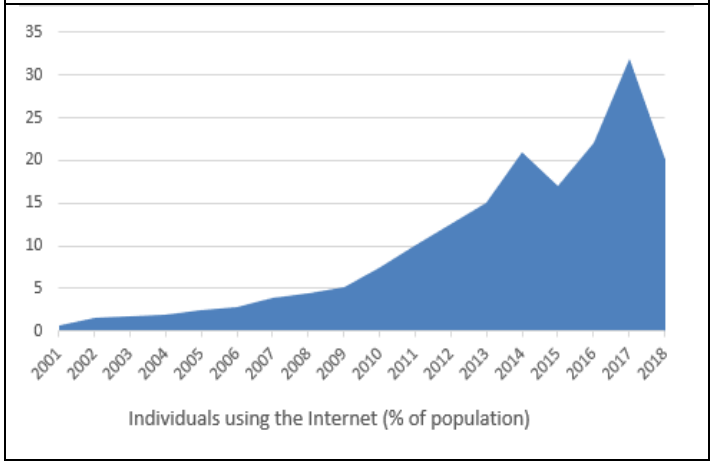
In this section, the extent of digitalisation and GVC participation in India are detailed. The macro picture of digitalisation in India was obtained from data related to internet infrastructure in India from World Bank (2020).

The first panel in Figure 1 shows that the percentage of the population using internet in India has increased since 2001, with a further, sustained momentum since 2010. A similar upward trend is seen in the second panel, the number of broadband subscriptions. The third panel shows an exponentital increase in the number of secure internet servers in the past decade, with less than 2 in 2010 to almost 400 in 2020.

**Figure 1: Digitalisation Trends in India**

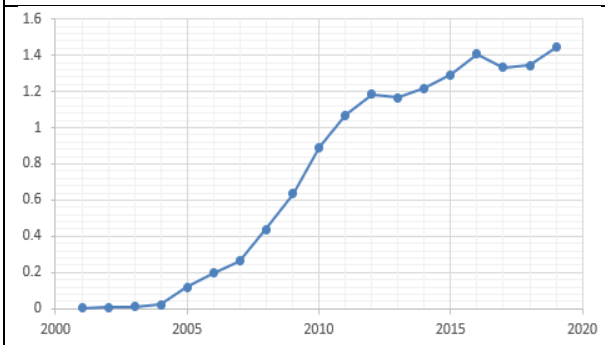
**Population Using Internet in India, 2001–2018**

(%)



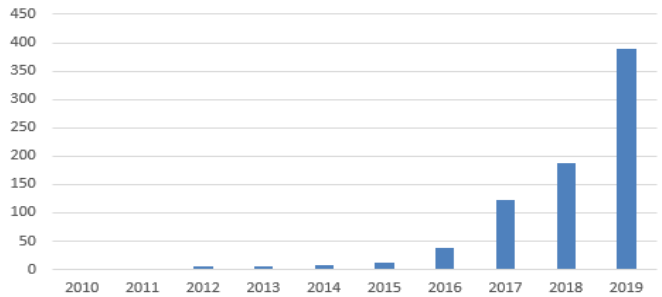

**Fixed Broadband Subscriptions, 2000–2020**

(per 100 people)




**Secure Internet Servers 2010–2019**

(per 1 million people)




Note: The time period in the third panel is from 2010 due to lack of data prior to 2010.
Source: Authors' compilation using World Bank (2020).

In addition, the World Bank's Digital Adoption Index (DAI) shows the improvement in India's digital adoption. The DAI measures the capacity and prepardness of a country to adopt and to explore digital technologies to promote development. The DAI consists of the simple average of three subindexes that are based across three dimensions: households, the government, and business (Table 1). Regarding India, all three subindexes have expereinced an increase over 2014 levels; consequently, India's overall DAI increased from 0.44 in 2014 to 0.51 in 2016, highlighting the country's improved adoption of digital technologies.

**Table 1: Digital Adoption Index**

| Country | Year | DAI | DAI Business Subindex | DAI People Subindex | DAI Government Subindex |
|---|---|---|---|---|---|
| India | 2014 | 0.442272395 | 0.430099308 | 0.160062328 | 0.736655533 |
| India | 2016 | 0.510771692 | 0.500528276 | 0.227437884 | 0.804348886 |

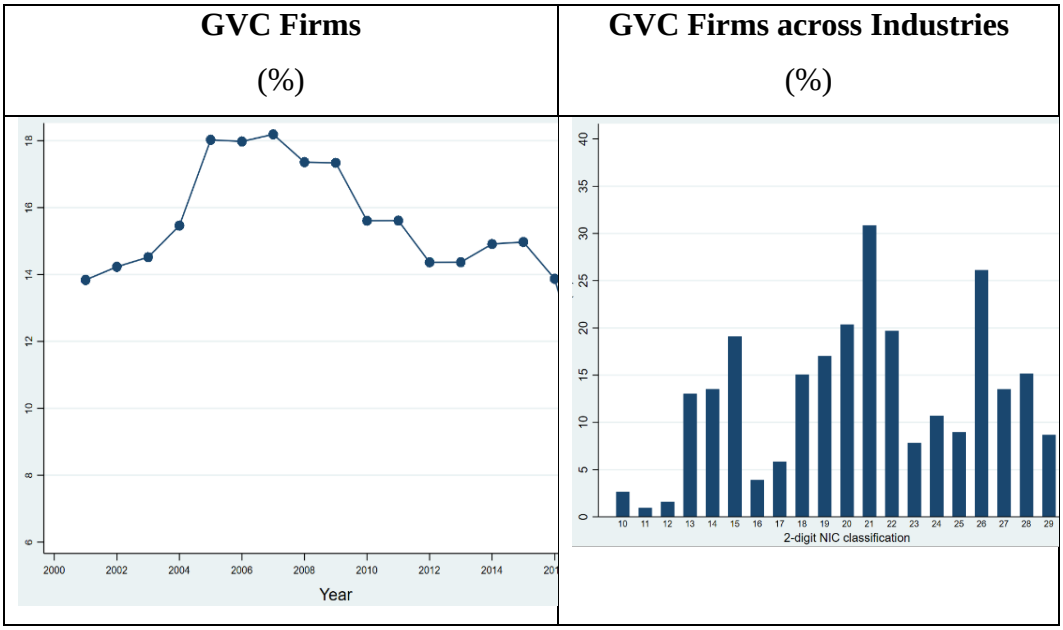
DAI = Digital Adoption Index.
Source: World Bank (2021).

Further, using firm-level data from the Prowess database provided by the Centre for Monitoring Indian Economy (CMIE), the involvement of firms in GVCs over the years, and how this varies across industries, is documented. The first panel in Figure 2 shows that the percentage of GVC firms – two-way trading firms that export and import at least 10% of their sales in India – rose until the global financial crisis. However, since the crisis, the number of firms participating in GVCs fell, in line with the global trend as noted in World Bank (2020). Trade within GVCs reached its peak around 2007, before plummeting due to the onset of the crisis.

The second panel shows the percentage of GVC firms across 2-digit National Industry Classification (NIC) manufacturing codes.[3] In this panel, other manufacturing (i.e., jewellery and related articles) has the highest GVC integration of firms. This is also the sector that is a significant contributor to India's export basket, followed by pharmaceuticals and computers.

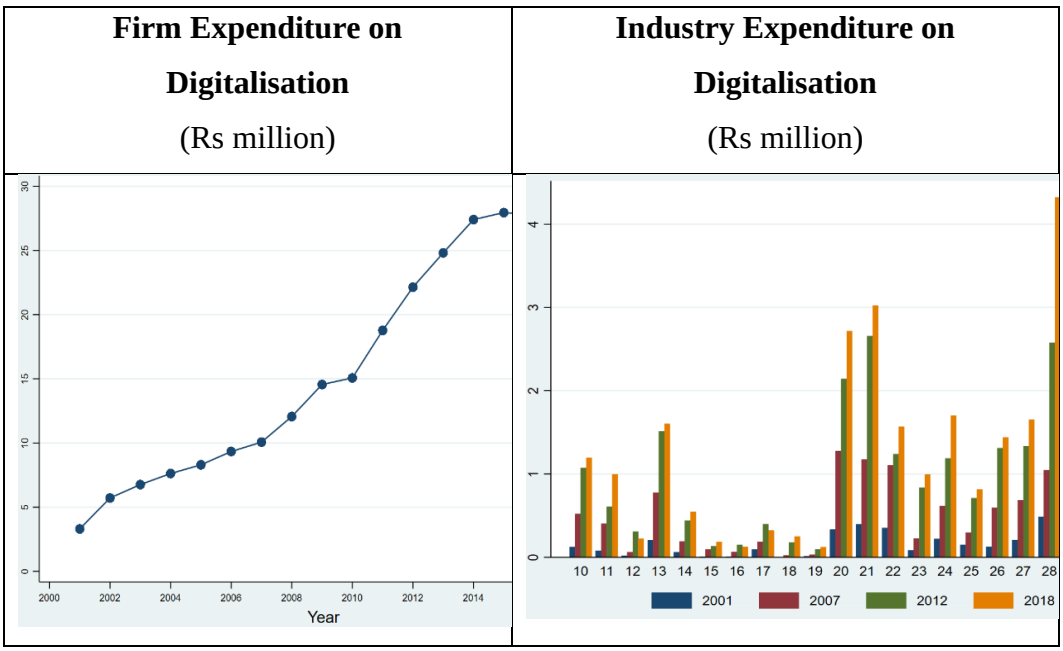
[3] 10, food products; 11, beverages; 12, tobacco products; 13, textiles; 14, wearing apparel; 15, leather and related products; 16, wood and products of wood; 17, paper and paper products; 18, printing and reproduction of recorded media; 19, coke and refined petroleum products; 20, chemical and chemical products; 21, pharmaceutical, medicinal, chemical, and botanical products; 22, rubber and plastic products; 23, other non-metallic mineral products; 24, basic metals; 25, fabricated metal products, except machinery and equipment; 26, computer, electronic, and optical products; 27, electrical equipment; 28, machinery and equipment; 29, motor vehicles, trailers, and semi-trailers; 30, other transport equipment; 31, furniture; and 32, other manufacturing.

**Figure 2: Trends of Firm Global Value Chain Particitpation**




GVC = global value chain.
Source: Authors' compilation from CMIE (2021).

**Figure 3: Trends in Firm Digitalisation**



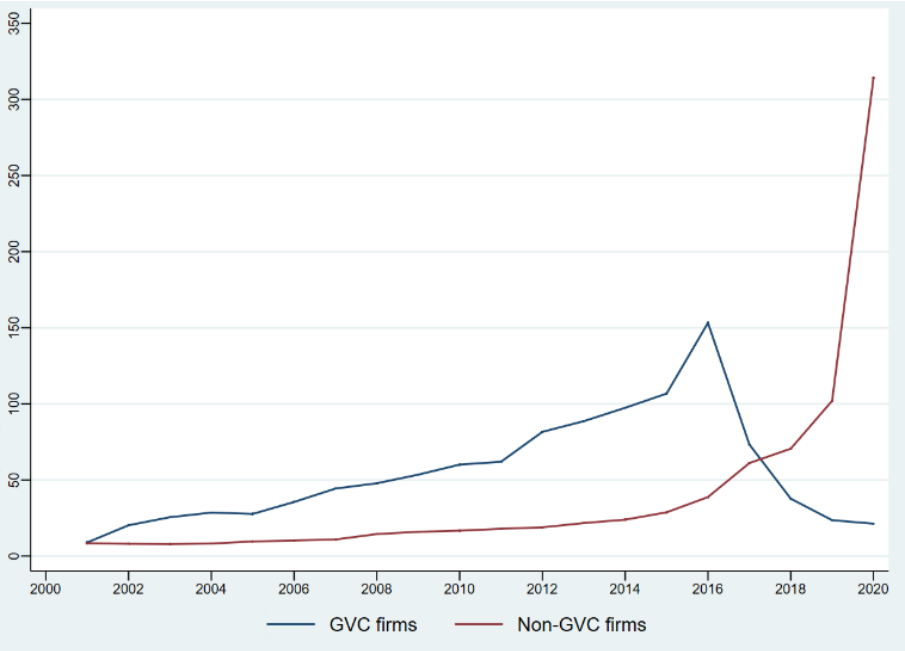

Source: Authors' compilation from CMIE (2021).

Further, the Prowess database provides information on the expenses incurred by firms on their digital infrastructure. The first panel of Figure 3 shows that the extent of firms' expenditure on digital infrastructure as a proportion of sales

increased, showing the rising importance of investments undertaken by firms over the past 2 decades. The second panel observes that across all industries, the level of investment in digital infrastructure has increased. However, substantial differences amongst industry expenditure on digitalisation emerged; the chemical, pharmaceutical, machinery, and automotive sectors had the highest levels of digitalisation.

**Figure 4: Average Firm Expenditure on Digital Infrastructure, Global Value Chain versus Non-Global Value Chain Firms**

(Rs million)




GVC = global value chain.
Source: Authors' compilation from CMIE (2021).

Figure 4 presents the average firm expenditure on digital infrastructure between GVC and non-GVC firms, enabling examination of the level of digitalisation. During the past 2 decades, GVC firms have invested more in boosting their digital infrastructure. However, since 2016, the spending on digital infrastructure has declined with the fall in the number of GVC firms (Figure 2). The broad trends documented in this section highlight an overall improvement in digitalisation in India and its nexus with the GVC integration of the firms.

## 4. Data and Variables

To evaluate the nexus between digitalisation and GVC participation, firm-level data were obtained from the Prowess database (CMIE 2021), which contains firm-level information procured from the audited financial statements of firms, Ministry of Company Affairs, and major stock exchanges, comprising exports, imports, sales, assets, liabilities, compensation, foreign promoters' shares in a firm, affiliations, and expenditures on fuel. The companies covered in the database account for more than 70% of economic activity in India's organised industrial sector (Topalova and Khandelwal, 2011). Firms in the database account for about 50% of India's export activity and 60% of import activity; the database is widely used and is extensively employed for firm-level analysis in India (Topalova and Khandelwal, 2011; De Loecker, Goldberg, Khandelwal, Pavicnik, 2016; Stiebale and Vencappa, 2018).

For empirical analysis, information on firms belonging to the manufacturing sector, classified at the two-digit NIC level, is employed. Although the Prowess database has information on more than 17,000 Indian manufacturing firms, those with missing values regarding sales, fixed assets, exports, imports, and expenditure on ICT and related services were dropped. Firms were also dropped if consecutive data for 3 years were unavailable. Therefore, a sample of 4,875 manufacturing firms corresponding to 43,708 firm year observations over 2001–2020 is used.

A key feature of GVC firms is their involvement in multiple countries with production dispersed across geographical borders. In the absence of a granular database that provides detailed information on the source of inputs, final use of exports and imports, and destination of exports, the majority of the firm-level literature pertaining to GVCs use the broad definition of GVC to identify GVC firms. According to this broader definition, a GVC firm is that involved in both exporting and importing activities simultaneously (Antràs, 2020; Urata and Baek, 2020). Consequently, firms are identified as GVC firms that simultaneously import and export at least 10% of sales as GVC firms in the sample.

It is well recognised in the literature that digitalisation is a complex phenomenon encompassing an array of activities, such as purchase of ICT products, upgrade of existing or purchase of new software, and investment in cloud

computing (Barney, 1991; OECD, 2014; Yoo, Boland, Lyytinen, Majchrzak, 2012; Tjahjono, Esplugues, Ares, Palaez, 2017). Consequently, to capture the main variable of interest – digitalisation – information was drawn from firm expenditure on software development, ICT, and ICT-enabled services.

The Prowess database also contains firm product-level data on quantities and values of sales and production. It provides a 20-digit product code, which is closely related to International Standard Industrial Classification of All Economic Activities (ISIC) classification, similar to that of Harmonized System (HS) classification. Therefore, mapping of products reported in the Prowess database to their respective HS codes is feasible.

The sophistication of Indian products *(SOPHY)* as the sales-weighted average sophistication of the product is used, which captures the average tacit technological level of the product. Equation 1 details the measure of product sophistication (*PRODY*), which is measured following Hausman, Hwang, and Rodrik (2007).

$$SOPHY_{it} = \sum_k \frac{sales_{it}^k}{\sum_k^k Sales_{it}^k} PRODY_K \qquad (1)$$

From the sample of 43,708 firm-year observations, consistent product-level information was obtained for a subset of 11,480 firm product-year observations. In addition, information about travel-related expenditures (e.g., domestic and foreign travel by personnel, local commuting expenses, along with boarding and lodging expenditures) was found; contact-intensive firms are also distinguished from contact-diluted firms, allowing examination of how the lockdown resulting from the COVID-19 pandemic impacted firm GVC participation and how firm digital aptness matters.

A myriad of firm-level controls, guided by the existing literature, are noted. First, firm productivity is controlled for, as it is well documented in the literature that more productive firms find it easier to internationalise (Melitz, 2003; Lu, Shi, Luo, Liu, 2018). Second, foreign ownership and business group affiliation of the firms are controlled for, since such firms enjoy an advantage over access to resources, technology, and foreign markets when compared to others (Rigo, 2017). Third, to account for scale, firm size, measured as the log of a firm's total assets, is

controlled for (Minetti, Murro, Rotondi, Zhu, 2019). Fourth, the age of the firm is controlled for, but there is mixed evidence on the impact of age on firms' GVC participation since older firms have better networking ties and face lower sunk costs (Urata and Baek, 2020; Minetti and Zhu, 2011), which increase their GVC participation, so young firms face strong competition from existing firms. Young firms, however, are more adaptive to recent innovative changes and production technologies, gaining an edge over the competition (Upward, Wang, Zheng, 2013). The age of the firm may thus have either a positive or negative impact on GVC participation.

Table 2 presents the definition of the key variables and controls used in the study; 14.5% of the firms in the sample are GVC firms. Around 6.0% of the firms are foreign-owned. Further, with the onset of the pandemic and various social distancing norms in place, contact-intensive firms (i.e., those with travel-related expenditures greater than the industry average) are more likely to be most affected. From the table, 24% of the sample firms are identified as contact-intensive firms.

**Table 2: Summary Statistics**

| Variable | Description | Obs | Mean | Std Dev | Min | Max |
|---|---|---|---|---|---|---|
| GVC | Exporting and importing at least 10% of sales | 43,708 | 0.145 | 0.352 | 0 | 1 |
| LnIT | Log of firm expenditure expenses incurred on software development, ICT, and ITES charges | 43,708 | 1.743 | 1.445 | 0.095 | 9.753 |
| LnTFP | Log of Total Factor Productivity following Levinsohn and Petrin (2003) | 43,708 | 4.183 | 1.096 | 0.370 | 11.109 |
| LnAge | Log of age of the firm where age is the number of years that the firm has been in operation | 43,708 | 3.197 | 0.566 | 0.693 | 4.615 |
| Group | Group affiliation dummy | 43,708 | 0.286 | 0.452 | 0 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Foreign | Foreign ownership dummy (> 10%) | 43,708 | 0.056 | 0.229 | 0 | 1 |
| LnSize | Log of total assets | 43,708 | 7.006 | 1.716 | 1.224 | 16.087 |
| Export | Dummy = 1 if firm exports and 0 otherwise | 43,708 | 0.578 | 0.493 | 0 | 1 |
| Import | Dummy = 1 if firm imports and 0 otherwise | 43,708 | 0.625 | 0.483 | 0 | 1 |
| LnSOPHY | Log of product sophistication index | 11,480 | 7.997 | 2.164 | 0.039 | 10.080 |
| Contact | Contact intensive = 1 if firm expenditure on travel > industry average and zero otherwise | 43,708 | 0.244 | 0.430 | 0 | 1 |

ICT = information and communications technology, ITES = ICT-enabled services.
Note: All variables are expressed in levels. However, for empirical analysis, lagged values of explanatory variables were used.
Source: Authors.

## 5. Methodology

To evaluate the impact of digitalisation on firms' GVC participation, a logit model is employed, guided by the binary nature of the dependent variable. Equation 2 presents the logistic regression model where:

$_i$ = a firm,

$_t$ = a year,

GVC = the dummy dependent variable,

*Digitalization* of the firm = the key variable of interest, and

**Z** = a vector of firm-level control variables, including time and industry fixed effects.

$$Logit(Pr(GVC_{it} = 1)) = \alpha + Digitalization_{it-1} + \boldsymbol{Z} + \epsilon_{it} \quad (2)$$

In the estimation, all explanatory variables (i.e., *Digitalization* and ***Z***) are lagged by 1 year, accounting for the fact that some predicted effects take time to materialise. For example, firms may undertake investment for developing

infrastructure at time $_{t,}$ but the firm may only reap its benefits after a certain period of time. Additionally, lagged values also account for possible simultaneity bias in the model. Note that dummy variables, such as foreign ownership of the firm and business group affiliation, are not lagged.

The role of digitalisation in technologically upgrading the firms is also investigated. In this regard, the literature on technological upgrading has highlighted the importance of past patterns of a firm's technological level, emphasising the possibility of inertia. Hence, the lagged value of a product sophistication index is incorporated to encompass the dynamic response between firms' past technology upgrading and independent variables in the model. By incorporating the lagged value of the dependent variable, the traditional fixed effect estimation leads to biased estimates. To overcome this, the bootstrap bias corrected fixed effect estimation is used. Equation 3 presents the regression model where:
$\boldsymbol{Z}$ = a vector of firm-level controls, including time fixed effects,
*Digitalisation* = the main variable of interest, and
*SOPHY* = the product sophistication index.

$$Ln(SOPHY)_{it} = \alpha + Ln(SOPHY)_{it-1} + Digitalization_{it-1} + \boldsymbol{Z} + \epsilon_{it} \qquad (3)$$

# 6. Results

## 6.1 Global Value Chains and Digitalisation

To estimate Equation (2), control variables, industry fixed effects, and year fixed effects are employed in a step-wise manner. Table 3 reports the odds ratio and marginal effects of the logit model. A firm's expenditure on digital infrastructure increases the odds of a firm participating in GVCs by 9% to 20%. These results are similar to the findings of Fort (2017), which highlighted that ICT firms are more likely to engage in fragmented modes of production. Further, concerning the control variables, more productive firms, foreign-owned firms, and large firms are more likely to integrate into GVCs, which is in line with the existing literature (Lu, Shi, Luo, Liu, 2018; Urata and Baek, 2020; World Bank, 2020).

**Table 3: Digitalisation and Global Value Chain Participation, Logit Model**

| | (1) | | (2) | | (3) | | (4) | |
|---|---|---|---|---|---|---|---|---|
| **VARIABLES** | **Odds** | **ME** | **Odds** | **ME** | **Odds** | **ME** | **Odds** | **ME** |
| L.lnit | 1.095*** | 0.00432*** | 0.983 | –0.000794 | 1.209*** | 0.00856*** | 1.152*** | 0.00659*** |
| | (0.0303) | | (0.0395) | | (0.0524) | | (0.0504) | |
| L.logtfplp | | | 1.291*** | 0.0117*** | 1.079 | 0.00342 | 1.344*** | 0.0138*** |
| | | | (0.0754) | | (0.0652) | | (0.0985) | |
| L.logage | | | 0.359*** | –0.0470*** | 0.900 | –0.00474 | 0.955 | –0.00217 |
| | | | (0.0356) | | (0.0988) | | (0.110) | |
| L.lnsize | | | 1.302*** | 0.0121*** | 1.617*** | 0.0217*** | 1.582*** | 0.0214*** |
| | | | (0.0628) | | (0.0848) | | (0.0861) | |
| Group | | | 1.487** | 0.0182** | 0.726* | –0.0144* | 0.871 | –0.00644 |
| | | | (0.233) | | (0.121) | | (0.149) | |
| Foreign | | | 1.902*** | 0.0295*** | 1.513** | 0.0187** | 1.456** | 0.0175** |
| | | | (0.295) | | (0.245) | | (0.234) | |
| Industry Dummy | | | | | No | | Yes | |
| Year Dummy | | | | | Yes | | Yes | |
| Observations | 37,890 | | 37,890 | | 37,890 | | 37,890 | |

Note: Standard errors are in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10.
Source: Authors.

## 6.2. Exporters and Importers

As the firm-level literature governing the GVC phenomenon identified GVC firms as those that are involved in both exporting and importing activities, this subsection disentangles the impact of digitalisation on export participation and import participation of Indian manufacturing firms. The empirical specification is analogous to Equation (2), with the dependent variable changing from GVC participation to export or import participation, respectively. Table 4 presents the finding of the empirical analysis, where columns (1) and (2) depict the digitalisation and export participation nexus, while columns (3) and (4) document the impact of digitalisation on import participation.

**Table 4: Digitalisation and Export and Import Nexus, Logit Model**

| | Exporting Firms | | | | Importing Firms | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | | (2) | | (3) | | (4) | |
| **VARIABLES** | **Odds** | **ME** | **Odds** | **ME** | **Odds** | **ME** | **Odds** | **ME** |
| L.lnit | 1.069* | 0.00541* | 1.001 | 4.75e-05 | 1.042 | 0.00393 | 0.983 | –0.00165 |
| | (0.0383) | | (0.0358) | | (0.0351) | | (0.0331) | |
| L.logtfplp | 1.128** | 0.00983** | 1.437*** | 0.0301*** | 1.174*** | 0.0152*** | 1.502*** | 0.0386*** |
| | (0.0568) | | (0.0793) | | (0.0536) | | (0.0767) | |
| L.logage | 2.537*** | 0.0760*** | 2.647*** | 0.0807*** | 1.660*** | 0.0479*** | 1.766*** | 0.0539*** |
| | (0.262) | | (0.264) | | (0.147) | | (0.151) | |
| L.lnsize | 2.228*** | 0.0655*** | 2.095*** | 0.0613*** | 1.885*** | 0.0599*** | 1.774*** | 0.0543*** |
| | (0.0976) | | (0.0922) | | (0.0761) | | (0.0719) | |
| Group | 0.868 | –0.0116 | 0.997 | –0.000289 | 1.589*** | 0.0438*** | 1.720*** | 0.0514*** |
| | (0.139) | | (0.153) | | (0.215) | | (0.221) | |
| Foreign | 1.634*** | 0.0401*** | 1.577*** | 0.0378*** | 2.084*** | 0.0694*** | 1.914*** | 0.0615*** |
| | (0.282) | | (0.270) | | (0.370) | | (0.334) | |
| Industry Dummy | No | | Yes | | No | | Yes | |
| Year Dummy | Yes | | Yes | | Yes | | Yes | |
| Observations | 37,890 | | 37,890 | | 37,890 | | 37,890 | |

Note: Standard errors are in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10.
Source: Authors.

From the table, the impact of digitalisation on firm export participation is weak, while the coefficient turns insignificant in the case of importing firms. However, exporting and importing are both integral to firms involved in GVCs, so the insignificant finding can be attributed to the different characteristics of two-way trading firms compared to those that only export or import. This is in line with the literature, which documented that the economic implications of two-way trading firms are different from firms involved in only a single mode of internationalisation (Rigo, 2020).[4] Most imports in the GVC context concern intermediates used in the country export basket. In this regard, digitalisation may have a greater implication for GVC firms by enabling improved and efficient coordination between these activities. Hence, comparing the results from Table 3 to those in Table 4, digitalisation plays a pivotal role in GVC participation of a firm – but not for those engaged only in one activity.

[4] First, two-way trading firms must incur sunk costs regarding both importing and exporting, so only the most productive firms self-select to becoming such firms (Aristei, Castellani, Franco, 2013). Second, these firms are larger both in terms of employment and assets, have more capital and skills, and are older in comparison to firms engaged in a single activity (Rigo, 2017). Third, two-way traders are more involved in innovative activities (Şeker, 2012; Aristei, Castellani, Franco, 2013).

### 6.3. Contact-Intensive Firms versus Others

The onset of the COVID-19 pandemic brought about a massive supply chain disruption across the globe, stressing the frailty of GVCs. As a response to the initial wave of the virus, the Government of India imposed a lockdown on the population; restrictions were, however, eased in the following months. During this period, many firms had to move aspects of their operations online, but some firms could not as they have more contact-intensive operations.

Given the social-distancing norms that are presently in effect across the globe, examining the role of digitalisation in shaping GVC participation of firms that are more contact-intensive is imperative. Table 5 shows that digitalisation has been a driving force for firms that are less contact-intensive – but unable to aid firms that are more contact-intensive. This could be due to the lower positions of Indian firms in GVCs; that is, they are often restricted to assembly activities, where ICT software usage may not be a defining factor. Digital adoption techniques that may help such firms include robotics and automation.The effective impact of digitalisation also warrants investment in non-digital sources aimed at reorganising and reconfiguring existing production processes, enabling firms to take advantage of digital infrastructure (Díaz-Chao, Sainz-González, Torrest-Sellenset, 2015; Cassetta et al., 2020). A lack of reorganisation within the internal structure of firms may restrict them from reaping the benefits of digitalisation. Indeed, less contact-intensive firms may have managed to mitigate some of the supply chain disruptions caused by the lockdown and social-distancing norms by coordinating their production processes with improved digitalisation, allowing them to continue operations with a reduced workforce and to share necessary information efficiently.

## Table 5: Digitalisation and Global Value Chain Participation, Contact-Intensive Firms versus Others

| | Contact-Intensive Firms | | | | | | Less Contact-Intensive Firms | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GVC | | Exporting | | Importing | | GVC | | Exporting | | Importing | |
| | (1) | | (2) | | | | | | (3) | | (4) | |
| VARIABLES | Odds | ME | Odds | ME | Odds | ME | Odds | ME | Odds | ME | Odds | ME |
| L.lnit | 1.018 | 0.00102 | 1.079 | 0.00512 | 0.994 | -0.00042 | 1.435*** | 0.0153*** | 1.113** | 0.00874** | 1.215*** | 0.0189*** |
| | (0.0665) | | (0.0669) | | (0.0610) | | (0.0925) | | (0.0559) | | (0.0567) | |
| L.logtfplp | 1.220 | 0.0117 | 1.536*** | 0.0290*** | 1.955*** | 0.0455*** | 1.310*** | 0.0114*** | 1.343*** | 0.0241*** | 1.346*** | 0.0288*** |
| | (0.190) | | (0.219) | | (0.271) | | (0.113) | | (0.0831) | | (0.0762) | |
| L.logage | 0.853 | –0.00935 | 2.521*** | 0.0625*** | 2.302*** | 0.0566*** | 0.872 | –0.00581 | 2.325*** | 0.0691*** | 1.537*** | 0.0418*** |
| | (0.173) | | (0.473) | | (0.394) | | (0.117) | | (0.266) | | (0.148) | |
| L.lnsize | 1.761*** | 0.0333*** | 2.243*** | 0.0546*** | 1.669*** | 0.0348*** | 1.530*** | 0.0180*** | 2.088*** | 0.0603*** | 1.903*** | 0.0624*** |
| | (0.181) | | (0.216) | | (0.151) | | (0.105) | | (0.112) | | (0.0931) | |
| Group | 0.664 | –0.0241 | 1.004 | 0.000248 | 1.324 | 0.0191 | 0.837 | -0.00754 | 0.952 | –0.00404 | 1.890*** | 0.0618*** |
| | (0.184) | | (0.248) | | (0.298) | | (0.168) | | (0.172) | | (0.282) | |
| Foreign | 0.796 | –0.0134 | 2.302*** | 0.0564*** | 2.440*** | 0.0605*** | 2.130*** | 0.0320*** | 1.595** | 0.0383** | 2.361*** | 0.0834*** |
| | (0.216) | | (0.745) | | (0.802) | | (0.441) | | (0.339) | | (0.532) | |
| Industry Dummy | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Year Dummy | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Observa-tions | 9,212 | | 9,414 | | 9,414 | | 28,476 | | 28,476 | | 28,476 | |

GVC = global value chain.
Note: Standard errors are in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10.
Source: Authors.

### 6.4. Product Upgrading and Digitalisation

It is well established in the literature that firms from developing countries participating in GVCs often begin their participation at the lower end of GVCs, undertaking low value-added activities (Taglioni and Winkler, 2016). However, once a firm is integrated into a GVC, the objective is to upgrade along the value chain to perform higher value-added activities, increasing gains through such participation (World Bank, 2020). In this context, whether digitalisation facilitated product upgrading of Indian manufacturing firms is examined.

Table 6, columns (1) and (2) show the findings of the bootstrap-corrected fixed effect model, where an insignificant impact of digitalisation on product upgrading is found. There is a significant level of persistence in terms of product upgrading, depicted by a positive and significant coefficient of the lag value of product sophistication. However, while examining the digitalisation and product upgrading nexus, reverse causality is possible, stemming from higher upgrading, which leads to increased dependence on digital infrastructure. In this regard, failing to account for this reverse causality will lead to biased estimates. Thus, the system-generalised method of moments (GMM) approach is used, as well as a third lag of the endogenous variables as instruments. Columns (3), (4), and (5) document the findings of the system-GMM analysis.

The impact of digitalisation remains insignificant, perhaps due to the fact that much of the Indian manufacturing industry is still confined to low value-added activities. As a result, logistical improvement in the form of digitalisation may not aid the upgrading of firms that are involved in assembly activities. Further, the post-estimation test shows that AR (2) is insignificant, and that the null of the Hansen test cannot be rejected, validating the results of the system-GMM estimates.

**Table 6: Digitalisation and Product Upgrading**

| | **Fixed-Effects** | | **System-GMM** | | |
|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** |
| | lnpdy | lnpdy | lnpdy | lnpdy | lnpdy |
| Llpdy | 0.602*** | 0.642*** | 0.978*** | 1.054*** | 1.041*** |
| | (.013) | (0.014) | (0.048) | (0.037) | (0.035) |
| L.lnit | –0.007 | –0.013 | –0.045 | –0.040 | –0.034 |
| | (0.014) | (0.014) | (0.040) | (0.031) | (0.039) |
| L.logtfplp | –0.083*** | –0.023 | –0.013 | –0.014 | 0.005 |
| | (0.029) | (0.031) | (0.023) | (0.017) | (0.020) |
| L.logage | –0.283*** | –0.050 | –0.051** | 0.011 | 0.011 |
| | (0.063) | (0.126) | (0.022) | (0.020) | (0.021) |
| L.lnsize | 0.034 | 0.022 | 0.025 | 0.031 | 0.023 |
| | (0.027) | (0.022) | (0.028) | (0.021) | (0.028) |
| Foreign | 0.036 | 0.025 | 0.048 | 0.045* | 0.032 |
| | (0.052) | (0.046) | (0.035) | (0.026) | (0.026) |
| Group | | | –0.012 | 0.004 | 0.003 |
| | | | (0.022) | (0.017) | (0.025) |
| _cons | | | 0.342 | –0.622 | –0.466 |
| | | | (0.494) | (0.379) | (0.389) |
| AR(1) | | | 0.000 | 0.000 | 0.000 |
| AR(2) | | | 0.233 | 0.231 | 0.232 |
| Hansen Test | | | 0.054 | 0.467 | 0.377 |
| Year Dummy | | | No | Yes | Yes |
| Industry Dummy | | | No | No | Yes |
| Observations | 8,690 | 8,690 | 9,470 | 9,470 | 9,470 |

Note: Standard errors are in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10.
Source: Authors.

# 7. Subsample Analysis

## 7.1 Technology Classification

It is acknowledged that the technology underpinning the production process is not homogeneous across firms. Firms in the automotive industry, for example, are more technology-intensive when compared to firms from the textile industry. As a result, technological heterogeneity must be factored in across industries. To this end, following Parameswaran (2009), manufacturing industries are classified into two categories: technology-intensive and low-technology.[5]

Table 7 presents the impact of digitalisation on GVC participation of firms grouped into these categories. The impact is weakly significant for firms from technology-intensive industries and significant for low-technology industries. Based on the odds ratio, the odds of low-technology firms participating in GVCs increased by 27% with improvement in firm digitalisation, compared to 11% for firms in technology-intensive industries. These findings show that by investing in digitalisation, firms from low-technology industries can increase their likelihood of integrating into GVCs.

[5] The industry classification is as follows:
(i) Technology-intensive industries include NIC 20, 21, 26, 27, 28, 29, 30, and 32; and
(ii) Low-technology industries include NIC 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 22, 23, 24, 25, and 31.

**Table 7: Digitalisation and Global Value Chain Participation, Technology Classification**

| | Technology-Intensive | | Low-Technology | |
|---|---|---|---|---|
| **Dependent Variable** | **GVC** | **GVC** | **GVC** | **GVC** |
| | **(1)** | **(2)** | **(3)** | **(4)** |
| **VARIABLES** | **Odds** | **ME** | **Odds** | **ME** |
| L.lnit | 1.107* | 0.00593* | 1.277*** | 0.00911*** |
| | (0.0619) | (0.00328) | (0.0876) | (0.00257) |
| L.logtfplp | 1.245** | 0.0128** | 1.576*** | 0.0170*** |
| | (0.114) | (0.00533) | (0.162) | (0.00382) |
| L.logage | 0.895 | –0.00649 | 0.986 | –0.000514 |
| | (0.136) | (0.00889) | (0.166) | (0.00626) |
| L.lnsize | 1.476*** | 0.0227*** | 1.533*** | 0.0159*** |
| | (0.102) | (0.00408) | (0.127) | (0.00306) |
| Group | 0.684* | –0.0222* | 1.032 | 0.00119 |
| | (0.155) | (0.0132) | (0.256) | (0.00924) |
| Foreign | 1.485* | 0.0231* | 1.623* | 0.0181* |
| | (0.301) | (0.0119) | (0.432) | (0.00995) |
| Industry Dummy | Yes | Yes | Yes | Yes |
| Year Dummy | Yes | Yes | Yes | Yes |
| Observations | 17,279 | 17,279 | 20,611 | 20,611 |

Note: Standard errors are in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10.
Source: Authors.

### 7.2. Small versus Large Firms

This section investigates if the impact of digitalisation in promoting GVC participation of Indian manufacturing firms is homogeneous. This follows from the existing literature, which posited that larger firms are more inclined to adopt new technological advancements (Haller and Siedschlag, 2011; Hagsten and Kotnik, 2017). Further, SMEs continue to lag with respect to digitalisation in comparison to large firms (Cassetta et al., 2020). As a result, it is plausible that the gains from digital adoption do not accrue evenly across firms of different sizes (Strange and Zucchella, 2017).

**Table 8: Digitalisation and Global Value Chain Participation: Firm Size**

| | Q1 | | Q2 | | Q3 | | Q4 | | Q5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Dependent Variable** | **GVC** | **GVC** | **GVC** | **GVC** | **GVC** | **GVC** | **GVC** | **GVC** | **GVC** | **GVC** |
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| **VARIABLES** | **Odds** | **ME** | **Odds** | **ME** | **Odds** | **ME** | **Odds** | **ME** | **Odds** | **ME** |
| L.lnit | 2.712*** | 0.0220*** | 1.767*** | 0.0221*** | 1.785*** | 0.0267*** | 1.428*** | 0.0160*** | 1.186*** | 0.0108*** |
| | (0.671) | | (0.270) | | (0.205) | | (0.145) | | (0.0781) | |
| L.logtfplp | 0.751 | –0.00631 | 0.799 | –0.00871 | 0.721** | –0.0151** | 1.098 | 0.00420 | 1.200 | 0.0115 |
| | (0.148) | | (0.116) | | (0.102) | | (0.146) | | (0.148) | |
| L.logage | 0.715 | –0.00739 | 1.121 | 0.00443 | 1.029 | 0.00130 | 0.846 | –0.00751 | 0.970 | –0.00194 |
| | (0.217) | | (0.266) | | (0.218) | | (0.186) | | (0.218) | |
| L.lnsize | 3.209*** | 0.0257*** | 1.094 | 0.00347 | 1.239 | 0.00987 | 1.368* | 0.0141* | 1.058 | 0.00357 |
| | (0.845) | | (0.265) | | (0.266) | | (0.231) | | (0.126) | |
| Group | 0.718 | –0.00728 | 0.522* | –0.0253* | 0.475** | –0.0343** | 0.458*** | –0.0350*** | 0.526** | –0.0407** |
| | (0.363) | | (0.194) | | (0.148) | | (0.134) | | (0.159) | |
| Foreign | 1.636 | 0.0108 | 3.365** | 0.0471** | 1.748 | 0.0257 | 0.737 | –0.0137 | 1.249 | 0.0141 |
| | (1.201) | | (1.663) | | (0.651) | | (0.253) | | (0.358) | |
| Year Dummy | Yes | | Yes | | Yes | | Yes | | Yes | |
| Industry Dummy | Yes | | Yes | | Yes | | Yes | | Yes | |
| Observations | 7,290 | | 7,490 | | 7,582 | | 7,766 | | 7,762 | |

Note: Standard errors are in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10.
Source: Authors.

In Table 8, firms are organised into five quantiles based on size; the impact of digitalisation is significant across firms of all sizes. However, a closer look at the magnitude of the marginal effects reported show that digitalisation has a greater impact on small (Q1, Q2) and medium (Q3) firms when compared to large firms (Q4, Q5). Marginal coefficients show that investment in digital infrastructure increases the probability of small firms participating in GVCs by 2.20%, and 2.60% for medium firms. Comparatively, the magnitude falls to 1.08% to 1.60% for large firms. Hence, investment in digital infrastructure is an important channel for SMEs, which provide them with the foundation to increase their global presence through integration into GVCs.

### 7.3. Robustness

To further validate the findings, an alternative definition of GVCs is employed. Following Meyer (2020), GVC firms are defined as those that meet the following three criteria: (i) be an intensive importer (i.e., the total value of inputs imported by a firm should be at least one-third of the total value of inputs); (ii) export extensively (i.e., a firm must export at least two-thirds of its total sales); and (iii) be majority owned, have overseas investment in foreign companies, or be affiliated with a business group that is involved in international trade extensively (i.e., if the business group imports more than two-thirds of the total material inputs across the group or exports a minimum of two-thirds of the total group output). This definition also takes into account the interaction between lead firms and local affiliates, leading to transmission of knowledge and technological know-how (Gereffi, 1999; Gereffi, Humphrey, Sturgeon, 2005; Gereffi and Fernandez-Stark, 2011).

Table 9 presents the findings of this analysis. The impact of digitalisation is still positive and significant across all specifications, highlighting the robustness of the findings.

**Table 9: Digitalisation and Global Value Chain Participation, Alternate Definition of Global Value Chain**

| Dependent Variable | GVC-R | | GVC-R | | GVC-R | | GVC-R | |
|---|---|---|---|---|---|---|---|---|
| | (1) | | (2) | | (3) | | (4) | |
| VARIABLES | Odds | ME | Odds | ME | Odds | ME | Odds | ME |
| L.lnit | 1.559*** | 0.00204*** | 1.252*** | 0.00139*** | 1.745*** | 0.00340*** | 1.630*** | 0.00298*** |
| | (0.0951) | | (0.105) | | (0.195) | | (0.156) | |
| L.logtfplp | | | 0.478*** | –0.00457*** | 0.331*** | –0.00676*** | 0.475*** | -0.00454*** |
| | | | (0.0701) | | (0.0711) | | (0.101) | |
| L.logage | | | 1.158 | 0.000906 | 5.319*** | 0.0102*** | 7.893*** | 0.0126*** |
| | | | (0.266) | | (2.327) | | (2.548) | |
| L.lnsize | | | 1.817*** | 0.00369*** | 2.743*** | 0.00616*** | 2.559*** | 0.00572*** |
| | | | (0.203) | | (0.543) | | (0.350) | |
| Year Dummy | No | | No | | Yes | | Yes | |
| Industry Dummy | No | | No | | No | | Yes | |
| Observations | 37,890 | | 37,890 | | 37,890 | | 37,890 | |

GVC = global value chain.
Note: Standard errors are in parentheses: ***p < 0.01, **p < 0.05, *p < 0.10.
Source: Authors.

## 8. Policy Implications and Conclusions

Although this study focuses on India, the results can have wide-scale policy implications for other developing countries. First, findings highlight the importance of fostering the digital ability of firms. Policies assisting digitalisation efforts enable a smoother entry of firms into GVCs. However, this channel does not seem to be operating via exports or imports, with digitalisation having an insignificant impact. The characteristics defining GVC firms are more than just mere exporting and importing, so the need for transforming pure exporters and importers into GVC firms requires research aimed at identifying the factors that push these firms towards the next step of becoming GVCs.

Second, the distinction between contact-intensive and -diluted firms shows that digitalisation has not penetrated the high contact-intensive sector, as revealed by the insignificant coefficient of the digitalisation measure. At present, these firms are not at a stage at which their core activities could be reduced through digital means. In this regard, policies aimed at reconfiguring the production process of contact-intensive firms and promoting a greater integration of digital means would help firms become more resilient to shocks similar to that inflicted by the COVID-19 pandemic.

Third, the subsample analysis undertaken in this study underscores the importance of digitalisation in promoting GVC participation of low-technology industries and SMEs. These findings provide policymakers with an avenue to draft policies that provide SMEs and low-technology firms with the necessary digital infrastructure to boost their endeavours in participating in GVCs. Finally, given the frailty of GVCs, digitalisation provides a platform for policymakers to promote integration of Industry 4.0 in value chain operations to foster the resilience of various supply chains, which is key for post-COVID supply chain operations.

Moreover, greater digitalisation also has implications for the inventory management of firms involved in supply chains. Digitalisation is crucial to providing flexibility to GVCs by moving certain aspects of production to digital and virtual activities (Kimura, Thangavelu, Narjoko, Findlay, 2020). Finally, digitalisation also promotes greater repository of critical data pertaining to value chain operations, which is crucial in fostering policies to tackle, for example, pandemics in the future. This study provides policymakers with insight into the effects of digital aptness on the expeditiously growing phenomenon of GVCs.

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