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Digitalisation, Exports, and Firm Performance: A Case of Indian Manufacturing[1]

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Abstract: *This study contributes to the literature on digitalisation in developing countries by examining its role in export intensity and firm productivity in Indian manufacturing from 2000 to 2021. Using fixed effects and the system generalised method of moments (GMM) model, the analysis draws on firm-level data from the Prowess database, encompassing approximately 11,000 manufacturing firms.*

The findings reveal that digitalisation amongst India's manufacturing firms is positively associated with both export intensity and productivity, after accounting for firm characteristics and heterogeneity. Specifically, a 1% increase in digital intensity corresponds to a 0.16% increase in exports. This effect is further enhanced when expenditure on internet services and software development is included, raising the export impact to 0.21% per 1% increase in digital intensity. Additionally, the results indicate that a 1% increase in digitalisation intensity leads to a 0.8% growth in total factor productivity.

These findings have significant policy implications, particularly as digitalisation increasingly shapes the global and Indian economies. They underscore the need for strategies to promote digital adoption in manufacturing to enhance competitiveness and productivity.

Keywords: digitalisation, productivity, exports, servicification, manufacturing, India

JEL classifications: C33, D24, F14, J24, L60, O33

[1] Final draft prepared for the Servicification, Structural Transformation, and the Pandemic Recovery Fourth Phase Study. Please do not quote without author's permission.

1. Introduction

The fourth industrial revolution is characterised by the emergence of new business models with more valuable resources. New technologies such as robotics, component manufacturing, the internet, big data, and artificial intelligence (AI) are being widely applied to manufacturing. Firms are gradually adopting technology to increase efficiency of their business processes. This is changing the nature and process of cross-border businesses (Alcácer and Delgado, 2016).

Digital technology creates opportunities to accelerate growth. Firms that face more competition use digital technology more intensively and effectively. It enables them to reduce their costs and compete with their competitors in both domestic and international markets through inclusion, efficiency, and innovation. Inclusion implies more firms are able to sell new products to new destinations through e-commerce, even if they are smaller and younger than offline firms. Efficiency is improved by better utilisation of their capital and labour through availability of real-time data compared to offline suppliers. Innovation in online platforms and services enable firms to exploit economies of scale as opposed to conventional business models in retail, transport, and banking.

India's consumer-driven digital revolution is well underway, despite the country's businesses adopting technology in different ways and the growing divide between digital leaders and other companies. With 820 million internet users in September 2022 (TRAI, 2023), India is amongst the largest and fastest-growing countries for digital consumers, trailing only China. It is expected that the number of internet users in India could hit 1 billion as early as 2025. The total aggregated data consumption as of June 2023 was 69,505,508 gigabytes. The total wireless data usage in India grew at a rate of 7.60% from 41,790 petabytes (PB) in March 2023 to 44,967 PB in June 2023. Out of total data wireless usage, 2G data usage was 46 PB, 3G data usage was 353 PB, 4G data usage was 42,505 PB, and 5G data usage was 2,063 PB during the April 2023–June 2023 quarter. The contribution of 2G, 3G, 4G, and 5G data usage to the total volume of wireless data usage was at 0.10%, 0.78%, 94.53%, and 4.59%, respectively (TRAI, 2023). Amongst emerging economies, India is digitising faster than any other country except for Indonesia – and there is plenty of room to grow: just over 40% of the populace has an internet subscription. Based on current trends, there were 936.16 million internet users in India by December 2023 . (TRAI, 2023).

According to the McKinsey Global Institute's assessment of over 600 companies, the adoption of digital technology has varied by industry. Enterprise resource planning, customer relationship management, and search engine optimisation software tools are used by digital leaders in the top quartile of adopters two to three times more frequently than by businesses in the lowest quartile, and centralising digital management is about 15 times more common. Small businesses are outpacing large ones in other areas, such as accepting digital payments and using social media and video conferencing to reach and support customers. Overall, firm size is not always a differentiator. Large firms are far ahead in digital areas that require large investments, such as making sales through their own websites (McKinsey Global Institute).

In most of India's economic sectors, digital applications could become widespread. Digital communication services, electronics manufacturing, information technology, and business process management are amongst the main digital industries that might double their gross domestic product to US$355 billion to US$435 billion by 2025. Newly digitising industries such as retail, logistics, energy, healthcare, financial services, agriculture, education, and labour markets could generate between US$10 billion and US$150 billion more in economic value by 2025. These industries benefit from digital applications that increase productivity, cut down on waste, decrease fraud, and better match supply and demand. Between 60 and 65 million jobs could be created by 2025 as a result of the productivity the digital economy has unlocked, many of which would require functional digital skills. For 40 million to 45 million workers whose employment may be displaced, retraining and redeployment will be crucial.

In India, the digital landscape includes restructuring of producer–client interactions in sectors such as logistics, retail, agriculture, and healthcare. For instance, digital solutions are mapping out the most efficient routes and monitoring cargo movements on highways; e-retailing and digital marketing are growing alongside traditional retail outlets; telemedicine and digital consultations are making healthcare opportunities available in inaccessible areas; and lending and insurance payments in agriculture are becoming more data driven.

This study tries to fill the gap in the digitalisation literature by studying its impact on exports and productivity for developing countries. This study is based on India's manufacturing firms over the period 2000 to 2021. The results indicate that digitalisation is positively associated with higher export intensity and firm productivity after controlling for other firm characteristics and firm heterogeneity.

The outline of the rest of the paper is as follows. Section 2 provides a brief literature review. Section 3 discusses the trend of digitalisation in Indian in general and Indian manufacturing in particular. Data and construction of variables are presented in section 4.

Section 5 provides the model specification and estimation results, whilst section 6 concludes with relevant policy recommendations.

2. Extant Literature

In this paper, we examine the relationship between digitalisation and export performance of India's manufacturing firms. The positive association between digitalisation and exports has been demonstrated by many studies (e.g. Añón Higón and Bonvin, 2022; Fernandes, et al., 2019; Kneller and Timmis, 2016). This is because digital transformation can reduce both fixed and variable costs. For instance, the internet can reduce the costs incurred during internationalisation by reducing trade barriers and promoting exports (Dethine, Enjolras, and Monticolo, 2020; Kim, 2020). Digitalisation transformation through artificial intelligence can positively impact the performance of exporting firms by providing cheaper communication and improved access to foreign markets (Fernandes, et al., 2019; Cassetta, et al., 2020). Application of digital technologies can also make production and business processes more productive and efficient (Rehnberg and Ponte, 2017).

Technological change is considered an important precursor for better export performance and this is possible through digitalisation (Azar and Ciabuschi, 2017; Dalenogare, et al., 2018). Atasoy (2021) finds that increase in digitalisation of a firm could lead to export and product sophistication. In addition, digitalisation enables firms to develop business relationships with other firms, which aids in marketing, innovation, and competition (Freund and Weinhold, 2004; Bianchi and Mathews, 2016).

In fact, digital infrastructure is crucial for firms to seamlessly integrate into global value chains (de Marchi, Giuliani, and Rabellotti, 2018). Gopalan, Reddy, and Sasidharan (2022) find that digitalisation encourages firms to participate in global value chains in 52 countries. Digitalisation also contributes to servicification of manufacturing firms through improved accessibility to complex business services wherein goods are sold as bundle goods together with services (Miroudot and Cadestin, 2017). Digitalisation positively impacts the service exports of the Association of Southeast Asian Nations (ASEAN-5[2]) countries (Tee, Tham, and Kam, 2020).

Many firm-level studies have examined the impact of digitalisation on exports for various countries. Portugal-Perez and Wilson (2012) show the importance of digital infrastructure on export performance for developing countries. However, there is little research on the impact of

[2] The ASEAN-5 countries are Indonesia, Malaysia, Philippines, Singapore, and Thailand.

digitalisation on the exports and productivity of firms in the Indian context. A study by Lal (2004) on the Indian textile industry finds positive impact of digitalisation on exports through the use of digital technologies in garment designing. Gautam (2017) shows that Indian firms using e-commerce can increase export intensity by 7.9%. Banga and Banga (2020) show that Indian manufacturing is losing export competitiveness in some key traditional sectors due to lesser value addition of digital services.

3. Digitalisation in Indian Manufacturing

Digitalisation has become a critical aspect of India’s manufacturing industry in recent years, with many manufacturers embracing digital technologies to boost exports, productivity, efficiency, and overall competitiveness. India has witnessed a growing digital ecosystem, which has resulted in the creation of numerous digital start-ups, as well as increased investments in research and development, digital infrastructure, and talent development in the country.

The advent of digitalisation has impacted the manufacturing industry in various ways. The following are some of the key aspects of digitalisation in India’s manufacturing sector. Automation has become a crucial aspect of digitalisation, with many Indian manufacturers increasingly adopting automation in their production processes to boost efficiency, quality, and productivity. By automating their processes, manufacturers have been able to reduce labour costs, improve product quality, and boost efficiency, which ultimately results in firm profitability. Artificial intelligence (AI) technology has become an essential component of digitalisation in the manufacturing industry. AI technology enables manufacturers to analyse production data, identify trends, and optimise production processes. It also enables manufacturers to make real-time decisions based on the data generated by sensors and other devices. In India, AI technology is being used to optimise supply chain management, production planning and scheduling, and customer demand forecasting.

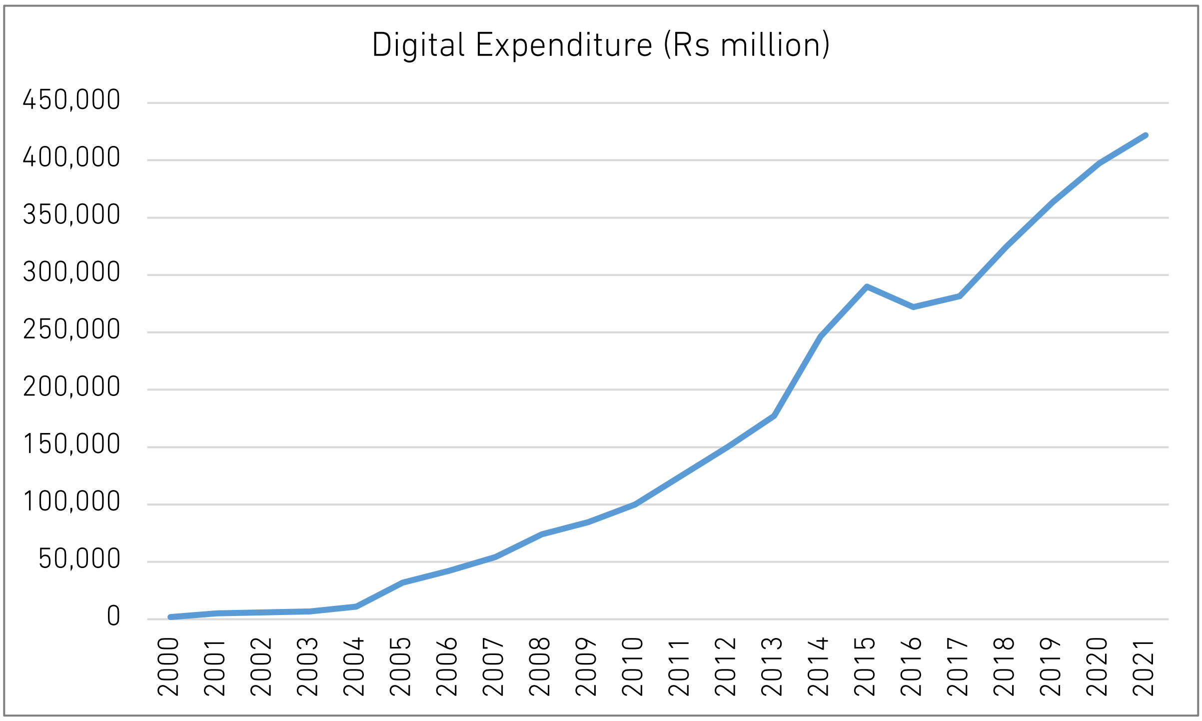
The Internet of Things (IoT) is another critical aspect of digitalisation in India’s manufacturing sector. IoT technology enables manufacturers to connect machines, sensors, and devices to the internet, enabling them to collect and analyse data in real-time. IoT technology also enables manufacturers to monitor and control production processes remotely, which results in increased efficiency and productivity. In India, IoT technology is being used in manufacturing processes such as inventory management, quality control, and asset tracking. Data analytics is an essential component of digitalisation in India’s manufacturing sector. It enables manufacturers to analyse production data and identify areas for improvement. By analysing production data, manufacturers can optimise their production processes, reduce waste and errors, and improve the overall quality of their products. Data analytics also enables manufacturers to monitor customer feedback and improve their products to meet customer demands. In India, data analytics is being used to improve production efficiency, quality control and supply chain management.

India's digital adoption has improved, as evidenced by the World Bank's Digital Adoption Index (DAI). The DAI suggests a nation's ability and readiness to implement digital technologies in order to advance development. The DAI is made up of the simple average of three sub-indices based on the government, business, and household sectors. All three of the sub-indices for India have increased from their 2014 levels; as a result, the country's overall DAI increased from 0.44 in 2014 to 0.51 in 2016, demonstrating the better adoption of digital technology in that country.

However, there are also challenges that must be addressed to ensure the success of digitalisation in India’s manufacturing sector. One of the key challenges is the availability of skilled workers who can operate and maintain digital technologies. These require significant investment in talent development and training programmes. Another challenge is the high cost of implementing digital technologies which can be a barrier for small and medium-sized enterprises. It requires significant investment in research and development (R&D), digital infrastructure, and technology deployment. This requires a favourable business environment, that can support these investments, which means that the government can play a critical role in creating the necessary regulatory framework to support the growth of digitalisation in India’s manufacturing industry. Figure 1 explains the trends in digital expenditure of India’s manufacturing firms over 2000–2021 according to the data collected from the Prowess database. The figure shows that there is a gradual increase in digital expenditure during 2000–2021 with a slight slump during 2015–2017. This is a clear indication of increased digitalisation levels amongst these firms.[3]

[3] We have utilised data on manufacturing firms based on the two-digit National Industrial Classification level, as collected from CMIE. Observations with missing or negative values have been excluded from the dataset. Additionally, firms have been omitted if consecutive data for 3 years were unavailable. As a result, this study employs an unbalanced panel dataset of approximately 11,000 manufacturing firms covering the period 2000–2021. Accordingly, Figure 1 is based on this unbalanced panel dataset for the specified time period.

Figure 1: Digital Expenditure of India's Manufacturing Firms (2000–2021)



Source: Author's calculations from Prowess database.

4. Data and Variables

We use firm-level data collected from the Prowess database of the Centre for Monitoring Indian Economy. The data include manufacturing, services, utilities, and finance. We have used information on firms belonging to the manufacturing sector, based on the two-digit National Industrial Classification level. The Prowess database contains information on more than 17,000 manufacturing firms. Observations with missing or negative values from the dataset have been excluded. We have also excluded firms from our dataset if consecutive data for 3 years were not available. Therefore, a sample of approximately 11,000 manufacturing firms for the period 2000–2021 is used.

The capital stock was proxied by the value of total fixed assets. Since the number of workers employed was not given in the dataset, the labour input was calculated by normalising the wage bill of each firm by the average wage prevailing in a given industrial sector in a given year provided in the Annual Survey of Industries published by the Government of India. After cleaning the data, our final dataset was an unbalanced panel of approximately 141,500 firm-year observations. Other firm indicators such as sales, value added, exports of goods and services, purchase of services inputs, gross/net fixed assets, and material inputs, and R&D expenses etc., have been used for this study.

Digitalisation of firms is the key variable of interest of this research. It is a complex phenomenon comprising activities, such as purchase of information and communications technology (ICT) products, upgrade of existing or purchase of new software, and investment in cloud computing (Barney, 1991; OECD, 2014; Yoo, et al., 2012). We use three types of digital intensity index for this analysis. The construction of the *DigitalIndex1* is based on capital expenditure of the firm (Banga and Banga, 2020). We also have information on software and internet expenditures. Using these information, we have constructed *DigitalIndex2* and *DigitalIndex3* to obtain alternative definition of digitalisation. These indices are used to check the robustness of our results to alternative definition of digitalisation. We have also used other firm-level control variables such as export intensity, technology, labour productivity, size (proxied by deflated gross fixed assets), and experience (difference between reporting year and incorporation year) and experience square of the firm. The expenditure on services inputs is the sum of expenditures incurred on outsourced professional jobs; marketing, advertising, and distribution; insurance premiums; and financial and nonfinancial services. We use the variable, *servicification*, for measuring the extent of services input used in manufacturing, measured as the share of services input expenditure in total sales. We obtain the deflators by matching two-digit National Industrial Classification codes with KLEMS codes for 2001–2019, from the Reserve Bank of India website (see Appendix for detailed explanation). We have considered 2011–2012 as the base year. For the years 2020 and 2021, the price deflators are calculated using National Accounts Statistics data.

5. Empirical Strategy

In order to examine the impact of digitalisation on exports intensity of manufacturing firm the following model specifications are used.

$$Exp_{it} = \alpha_0 + \alpha_1 Exp_{it-n} + \alpha_2 Digit\,\text{int}_{it} + \alpha_3 Z_{it} + \gamma_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where *i* is the firm, *t* is the year and *n* is the number of lags included in the model; *Exp.* is the export of goods and services taken together. The lagged values of export capture the effect of sunk costs (Roberts and Tybout, 1997; Bernard and Wagner, 2001). The key explanatory variable, digital intensity (*DigitintIndex*) is constructed by taking its alternative definitions of digital intensity; *Z* is a vector of covariates which include technical knowhow assets, R&D expenses, labour productivity, age of the firm, size of the firm, and service input intensity of the firm. γ_i and γ_t represent firm and year specific fixed effects, respectively. ε is residual and expected value of the residual i.e., $E(\varepsilon_{it}) = 0$ for all i and t. Ordinary least squares estimates will be biased and inconsistent due to the presence of unobserved firm-specific variables. Fixed effects estimates will not produce the desired result since the explanatory variables also include lagged values of the dependent variable, suggesting the presence of endogeneity in the data. We employ the system generalised method of moments (GMM) estimator to control for endogeneity and unobserved heteroscedasticity. The validity of system GMM estimations is verified by Hansen's *J* test of over-identifying restrictions (Arellano and Bond, 1991). In additions to this, AR(2) level guarantees that the first difference residuals do not contain any second order serial correlation at a *p value > 0.05*. Lastly, in accordance with Roodman (2009), the number of instruments in the model is less than the number of groups in the panel.

5.1. Digitalisation and Exports

Descriptive statistics are reported in Table 1. Regression results of the impact of digitalisation on exports based on the fixed effects and system GMM are given in Table 2. The results reveal that digitalisation (using alternative forms of digital intensity indices) has a positive and statistically significant impact on firm exports. Further, firms that report a higher expenditure on computer and information technology (with or without software and internet services expenditure) as a share of total expenditure on plant and machinery, have a greater impact on exports. When the hardware ecosystem of the firm is tied with the internet, it improves export performance. Hence, robust internet services help firms access better market information and increase firm performance through participation in international trade (Fernandes, et al., 2019; Kim, 2020; Dethine, Enjolras, and Monticolo, 2020; Lal, 2004). Our result shows that 1% increase in digital intensity leads to an increase of 0.16% in exports on an average. The impact of digitalisation on exports improves when we add expenditure on internet services and expenditure on software development. Our result shows that 1% increase in digital intensity leads to an increase of 0.21% in exports on an average keeping other things constant. Amongst other determinants, labour productivity on firm's exports is found to be positive and significant (Banga and Banga, 2020; Alvarez, Faruq, and López, 2002). The coefficient of lag exports is positive and statistically significant. We find that 1% increase in exports in the previous period would increase exports in the current period by 0.67%, other things remaining constant. This result shows that sunk costs, captured by lagged exports have a positive and highly significant impact on exports of a firm (Meinen, 2015; Goldar, Banga, and Banga, 2018). The coefficient of servicification is positive and highly statistically significant (Kelle, 2013; Goldar, Banga, and Banga, 2018; Pattnayak and Chadha, 2022). . Technical know-how of the firm including software, database, and product design, is seen to be favourably impacting firm exports. Our result also shows that larger firms experience higher exports (Fryges, 2006). The result is robust to the alternative forms of digital intensity indices.

Table 1: Descriptive Statistics

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Digital1	138,612	4.061823	12.62176	0	100
Digital2	138,612	5.3331	14.81007	0	100
Digital3	138,670	5.379743	14.94112	0	100
Log size	140,133	14.89284	2.01133	6.43403	24.192
Tech_knowhow	141,542	5.42e+07	1.13e+09	8600000	1.40e+11
Servicification	141,541	1998.158	42924.34	99831.46	9985106
labourprod	124,697	9.670986	1.367732	–2.18452	20.4921
R&D dummy	141,542	1	0.3816465	0	1
Exp&Imp dummy	141,542	1	.4920211	0	1
Age	141,345	28.68	20.89	0	167
TFP	118,359	8.532207			
Dital&Export dummy	141,542	1	0.4646616	0	1

R&D = research and development, TFP = total factor productivity.
Source: Author's calculations.

Table 2: Estimated Coefficients for Determinants of Exports

Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	Fixed Effects			**System GMM**		
Digital1	0.0016** (0.050)			0.0016** (0.026)		
Digital2		0.0032*** (0.000)			0.0021** (0.014)	
Digital3			0.0031*** (0.000)			0.0022** (0.090)
Export (t-1)	0.5874*** (0.000)	0.5865*** (0.000)	0.5865*** (0.000)	0.67310*** (0.000)	0.6728*** (0.000)	0.6727*** (0.000)
Export (t-2)				0.0765*** (0.000)	0.0763*** (0.000)	0.0762*** (0.000)
Lab_Prod	0.0388*** (0.000)	0.0385*** (0.000)	0.0385*** (0.000)	0.0842*** (0.000)	0.0841*** (0.000)	0.0841*** (0.000)
Tech_knowhow	0.274***	0.272***	0.273***	0.437***	0.436***	0.437***

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Fixed Effects			System GMM		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Servicification	0.1058*** (0.000)	0.1033*** (0.000)	0.1035*** (0.000)	0.0117** (0.0123)	0.0117** (0.0332)	0.0116** (0.0400
R&D dummy	0.0753*** (0.000)	0.0752*** (0.000)	0.0750*** (0.000)	0.1816*** (0.000)	0.1823*** (0.000)	0.1824*** (0.000)
Exp&Imp dummy	0.2818*** (0.000)	0.2828*** (0.000)	0.2816*** (0.000)	0.4798*** (0.000)	0.4813*** (0.000)	0.4814*** (0.000)
Size	0.0965*** (0.000)	0.0977*** (0.000)	0.0977*** (0.000)	0 .0976* (0.000)	0.0984*** (0.000)	0.0985*** (0.000)
Age square	–0.0154** (0.0012)	–0.0112* (0.0100)	–0.0104* (0.0112)	–0.0231** (0.0035)	–0.0142* (0.0100)	–0.0153* (0.0245)
Constant	2.9465*** (0.000)	2.9474*** (0.000)	2.9474*** (0.000)	0.8411448*** (0.000)	0.8327*** (0.000)	0.8339*** (0.000)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Firm Effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2 (Within)	0.4163	0.4165	0.4165			
F-Statistic	3566.10 (0.000)	3569.89 (0.000)	3569.12 (0.000)			
(AR1) p-value				–24.19 (0.000)	–24.19 (0.000)	–24.19 (0.000)
(AR2) p-value				1.26 (0.206)	1.27 (0.204)	1.27 (0.203)
Hansen J Test				37.34 (0.800)	30.46 (0.256)	30.38 (0.234)
No. of observations	46,259	46,259		38,223	38,223	38,223

R&D = research and development, RFP = total factor productivity.
Notes*:* ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Robust standard errors are given in parentheses. Instruments are collapsed as suggested by Roodman (2009). Hansen test is a test for over-identifying restrictions, the null hypothesis is that the instruments are valid. Arellano–Bond test for AR(1), AR(2) in first differences, respectively, the null hypothesis for AR(1) is that the first-differenced regression errors show no first-order serial correlation, the null hypothesis for AR(2) is that the first-differenced regression errors show no second-order serial correlation.
Source: Author’s calculations.

5.2. Digitalisation and Productivity

Total Factor Productivity (TFP) is measured as a 'residual' (Solow, 1957) term, accounting for factors beyond capital and labour, such as R&D, capabilities, and technology. Coe and Helpman (1995) estimated cross-country growth spillovers from using R&D, whilst Grilliches (1973) estimated the influence of R&D on TFP. The idea of TFP has also been applied to study productivity and technical change in India (Basant and Fikkert, 1996). Our study looks at the impact of digitalisation on firm-level TFP for Indian manufacturing. We use digitalisation as an efficiency-enhancing technology and as one of the explanatory variables in our econometric specification to find firm-specific determinants of TFP increase. The digitalisation index that was previously defined has been utilised. The size of the company and disembodied technological intensity are the other factors influencing TFP growth that we examine with our model. In order to estimate TFP, we employ the Levisohn and Petrin (2003) technique.

Next, we examine the impact of the level of digitalisation on manufacturing productivity. Our model specification is given as follows:

$$TFPG_{it} = \beta_0 + \beta_1 TFPG_{it-n} + \beta_2 Digit\,\mathrm{int}_{it} + \beta_3 Z_{it} + \gamma_i + \gamma_t + \varepsilon_{it} \qquad (2)$$

where *i* is the firm, *t* is the year and *TFPG* is the measure of total factor productivity of a firm. As before, *DigitalIndex* is our key explanatory variable and is the measure of digitalisation. We hypothesise that the coefficient will be positive. *Z* is a vector of covariates that include *size* as a measure of firm size which is denoted by total assets (excluding software stock), technical know-how of the firm (disembodied technology) that capture its knowledge about software, database, product design, etc., labour productivity, research and development (R&D dummy) capturing a firm that spends on R&D is equal to 1 and zero otherwise, export and import dummy represents both ways trade, age of the firm representing the experience of the firm and service input intensity representing *servicification*. γ_i and γ_t represent firm and year specific effects. ε is the error term.

We estimate the model using fixed effects and system GMM. Any unobserved heterogeneity is eliminated by the panel fixed effects. In order to detect endogeneity caused by a bias in the omitted variable, additional control variables are included in the robustness checks. As a result, the model estimations are reliable. The findings are shown in Table 3, where we find a strong and positive correlation between the growth of total factor productivity and digital intensity. According to the prediction, there will be an average 0.8% rise in TFP growth for every 1% increase in digitalisation intensity. The coefficients of other determinants of firm productivity are statistically significant.

Table 3: Estimated Coefficients for Determinants of Productivity

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Fixed Effects			System GMM		
DigitalIndex1	0.0005*** (0.000)			0.0083*** (0.000)		
DigitalIndex2		0.0009*** (0.000)			0.0078*** (0.000)	
DigitalIndex3			0.0009*** (0.000)			0.0079*** (0.000)
Ln tfp(t-1)	0.0579*** (0.000)	0.0579*** (0.000)	0.0578*** (0.000)	0.1133*** (0.000)	0.1152*** (0.000)	0.1150*** (0.000)
Tech_knowhow	0.0048*** (0.000)	0.0048*** (0.000)	0.0049*** (0.000)	0.0241*** (0.000)	0.0209*** (0.000)	0.0219*** (0.000)
Servicification	0.0104*** (0.000)	0.0108*** (0.000)	0.0107*** (0.000)	0.0703*** (0.000)	0.0668*** (0.000)	0.0667*** (0.000)
R&D dummy	0.0612*** (0.000)	0.0613*** (0.000)	0.0614*** (0.000)	0.2483*** (0.000)	0.2459*** (0.000)	0.2460*** (0.000)
Exp&Imp dummy	0.0277*** (0.000)	0.0281*** (0.000)	0.0280*** (0.000)	0.1806*** (0.000)	0.1769*** (0.000)	0.1772*** (0.000)
Size	–0.0314*** (0.000)	–0.0312*** (0.000)	–0.031*** (0.000)	0.0459*** (0.000)	0.0464*** (0.000)	0.0464*** (0.000)
labourprod	0.8661*** (0.000)	0.8662*** (0.000)	0.8661*** (0.000)	0.7839*** (0.000)	0.7839*** (0.000)	0.7840*** (0.000)
Constant	0.2020*** (0.000)	0.1981*** (0.000)	0.1979*** (0.000)	–1.3231*** (0.000)	–1.329789 (0.000)	–1.3291*** (0.000)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Firm Effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2 (Within)	0.9319	0.9320	0.9320			
F-Statistic	152735.53 (0.000)	152862.72 (0.000)	152851.98 (0.000)			
(AR1) p-value				–20.04 (0.000)	–20.31 (0.000)	–20.30 (0.000)
(AR2) p-value				0.07 (0.941)	0.28 (0.782)	0.26 (0.793)
Hansen J Test				30.46 (0.289)	40.38 (0.234)	

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Fixed Effects			System GMM		
No. of observations	100,167	100,167	100,178	100,167	100,167	100,178

GMM = generalised method of moments.
Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Robust standard errors are given in parentheses. Instruments are collapsed as suggested by Roodman (2009). Hansen test is a test for over-identifying restrictions, the null hypothesis is that the instruments are valid. Arellano–Bond test for AR(1), AR(2) in first differences, respectively, the null hypothesis for AR(1) is that the first-differenced regression errors show no first-order serial correlation, the null hypothesis for AR(2) is that the first-differenced regression errors show no second-order serial correlation.
Source: Author's calculations.

6. Conclusion and Policy Implications

This study explores the role of digitalisation on export intensity and firm productivity of Indian manufacturing. Our empirical results suggest that the digitalisation of Indian manufacturing is associated with higher exports and firm productivity. These are important results and have significant policy implications, particularly at a time when digitalisation is impacting every aspect of the global and Indian economy. Additionally, higher sunk costs (indicating experience in the export market), increased labour productivity, innovation capability, and extent of servicification of the firm are also associated with greater exports and higher productivity of Indian manufacturing. The results are found to be robust to different measures of digital intensity indices such as spending on IT and computer systems, and ongoing costs for software and internet services.

In recent times, the big firms have been able to leverage on the availability of various digital infrastructure and are able to improve their export performance and efficiency, but the small firms are struggling since the majority of them rely on conventional production and marketing techniques. The issue requires attention in terms of government policy. The Indian government has implemented numerous initiatives aimed at enhancing the adoption of digital technology. These initiatives include incentivising online transactions, promoting digital literacy, especially amongst rural populations, and enhancing fundamental infrastructure like internet and electricity accessibility. However, many Indian firms have still not caught up with the pace of digitalisation in competing countries.

It is suggested that the regulatory landscape needs to be simplified when it comes to export-related payments in India. This varies across aspects such as investment, the number of workers, type of product produced, production location, quantity of output, etc. and often leaves out micro units due to their ineligibility. Furthermore, owing to diseconomies of scale and lack of adequate revenues to take care of costs accrued at various stages – production, marketing, shipping, etc. therefore, assuring financial support is crucial for their long-term growth. Overall, the digitalisation of India's manufacturing sector is driving growth, competitiveness, and innovation. However, there are challenges to overcome, including the need for skilled workers to operate and maintain digital technologies, the high cost of implementation, and the need to adapt to changing business models.

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Appendix

KLEMS Industries

Sl. No.	Description of Industry
1	Agriculture, Hunting, Forestry and Fishing
2	Mining and Quarrying
3-15	**MANUFACTURING SECTOR**
3	Food Products, Beverages and Tobacco
4	Textiles, Textile Products, Leather and Footwear
5	Wood and Products of Wood
6	Pulp, Paper, Paper Products, Printing and Publishing
7	Coke, Refined Petroleum Products and Nuclear Fuel
8	Chemicals and Chemical Products
9	Rubber and Plastic Products
10	Other Non-Metallic and Mineral Products
11	Basic Metals and Fabricated Metal Products
12	Machinery, not anywhere classified
13	Electrical and Optical Equipment
14	Transport Equipment
15	Manufacturing, not anywhere classified (nec.); recycling
16	Electricity, Gas and Water Supply
17	Construction
18-27	**SERVICE SECTOR**
18	Trade
19	Hotels and Restaurants
20	Transport and Storage
21	Post and Telecommunications
22	Financial Intermediations
23	Business Services
24	Public Administration and Defense; Compulsory Social Security
25	Education
26	Health and Social Work
27	Others

Source: Reserve Bank of India.

About the KLEMS Database

The India KLEMS dataset is the first comprehensive documentation of economy-wide measures of labour input, capital input, intermediate input, and multifactor productivity at the level of disaggregated industrial sectors comprising the entire Indian economy. The creation of this dataset was funded by the Reserve Bank of India with technical support from the Central Statistical Office, Government of India. The objective of India's KLEMS database is to create an internationally comparable productivity database at the industry level in a unified framework covering the entire Indian economy on relevant measures of productivity, employment creation, labour quality, capital formation, and productivity growth. For this, time series data on value added as well as gross output, capital, labour, and intermediate inputs for a harmonised industrial classification are constructed.

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