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Does Digitalisation Promote the Servicification of Manufacturing in China?

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Abstract: *This paper uses detailed firm-level and transactional-level trade data to examine the causal relationship between digitalisation and servicification in Chinese manufacturing firms. Using the novel approach of text mining and analysis, this paper constructs two firm-level measurements of digitalisation and servicification. Further, it explores the impact of digitalisation on services integration within manufacturing activities. We find digitalisation plays a crucial role in enhancing manufacturing servicification, enabling firms to produce and sell more service products. We also highlight that the two mechanisms through which digitalisation promotes servicification are digital technology and profitability. This paper contributes to the existing literature by developing the micro-level evidence of the digital transformation occurring within Chinese manufacturing firms and sheds light on the emerging services-led global value chain upgrading pattern.*

Keywords: digitalisation, servicification, manufacturing firms, text mining, text analysis

JEL Classification: F14, F23

1. Introduction

Digitalisation is becoming increasingly crucial in services trade due to the rapid transformation in the global economy. The rapid pace of globalisation and robotics (globotics) is changing the world economy quickly, driven by strong growth in digital technology (Baldwin and Forsid, 2020). Specifically, as the global value chains of manufacturing sectors are disrupted by the novel coronavirus disease (COVID-19) pandemic, firms have radically accelerated their adoption of digital technology, leading to a restructuring of the traditional manufacturing-led mode of economic development to service linkages and the services sector, especially in developing countries such as China (Kilic and Marin, 2020). Automation and robotics are changing the comparative advantages of developing countries in manufacturing sectors due to the low labour costs, allowing them to seek development patterns in services value chains.

Despite the rapid development of digitalisation and its vital role in driving manufacturing firms to engage in the services sector, however, few studies focus on the impacts of digitalisation on the servicification of manufacturing, especially at the micro level. This paper aims to address this gap by examining the effects of digitalisation on the servicification of manufacturing of Chinese manufacturing firms. Using detailed data combined from Chinese manufacturing firms and transactional-level trade data, this paper sheds new light on the causal relationship between digitalisation and the integration of services within manufacturing firms. Furthermore, this paper explores the possible mechanisms through which digitalisation facilitates the servicification process, thereby shedding light on the transformative effects of digitalisation on manufacturing firms' upgrading in global value chains (GVCs).

However, one challenge in this paper is accurately measuring both servicification and digitalisation at the firm level. To address this key issue, first, we estimate the servicification of manufacturing by focusing on income of firms. By analysing the income sources of Chinese-listed manufacturing firms, we identify and quantify the extent of services-related integration within their manufacturing operations. Simultaneously, we construct a robust measurement of digitalisation at the firm level using text analysis. Analysing the annual

reports of listed firms from 2000 to 2020, we identify and quantify textual references to digitalisation, which allows us to categorise and measure the level of digitalisation based on the frequency of related terms across five dimensions of digital development. These comprehensive measurements enable us to capture and analyse the relationship between digitalisation and the servicification of manufacturing in China.

Another challenge to achieving this is the potential endogeneity between digitalisation and the servicification of manufacturing at the firm level. To address the potential endogeneity issue, we employ various robustness checks alongside the baseline estimation using the ordinary least squares (OLS) approach. Specifically, we use the number of post offices and telephones in 1984 as the instrument of digitalisation. These historical indicators serve as instruments for digitalisation due to their relevance in reflecting the early stages of communication infrastructure development, which are essential aspects of digitalisation. By employing these instruments, we can minimise the bias arising from potential reverse causality or omitted variable issues, thus providing more robust and reliable results regarding the impact of digitalisation on the servicification of manufacturing in China.

In this paper, we find that digitalisation facilitates the servicification of manufacturing in Chinese manufacturing firms by enabling them to produce and sell more service products on average. Specifically, the improved productivity and profitability resulting from digitalisation are the fundamental mechanisms through which digitalisation promotes the service of manufacturing firms in China. The adoption of digital technologies enhances the overall productivity of these firms, leading to an increased provision of services within the manufacturing sector, including in-house services. Furthermore, digitalisation positively impacts the profitability of these firms, creating incentives for them to produce and sell more services to maximise their profits. After a series of robustness checks and controlling for the endogenous problem, these effects are robust.

This paper contributes to the literature in three aspects. First, we provide a relatively new perspective on the role of the digital economy in manufacturing development by examining the servicification of manufacturing, which reveals how digitalisation impacts the manufacturing sector. Second, we present micro-level evidence of the digital transformation

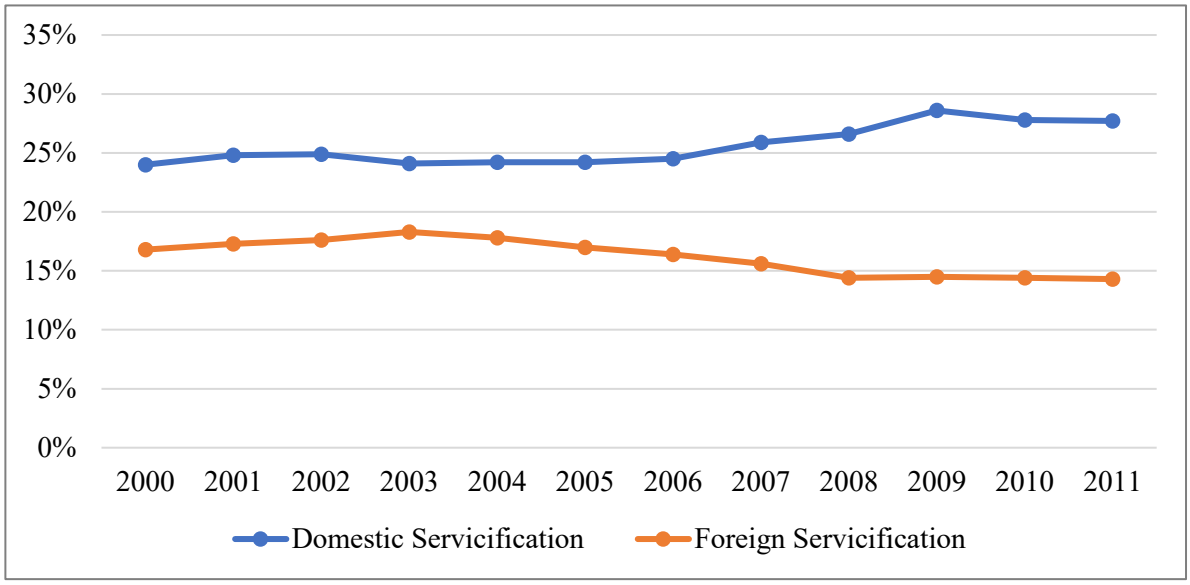
occurring within Chinese manufacturing firms through text analysis, which offers valuable insights into the specific ways digitalisation is being adopted and integrated at the firm level. Lastly, this paper sheds light on the emerging service-led pattern of GVCs upgrading for manufacturing firms, particularly in developing countries. By revealing this new trend, the paper highlights the changing dynamics and opportunities for manufacturing firms to enhance their competitiveness through service integration within GVCs.

The paper proceeds as follows. Section 2 introduces the current trends of servicification and digitalisation in China. Section 3 presents the measurements and datasets. Section 4 describes the empirical strategy and the empirical results. Section 5 provides the policy discussions.

2. Background

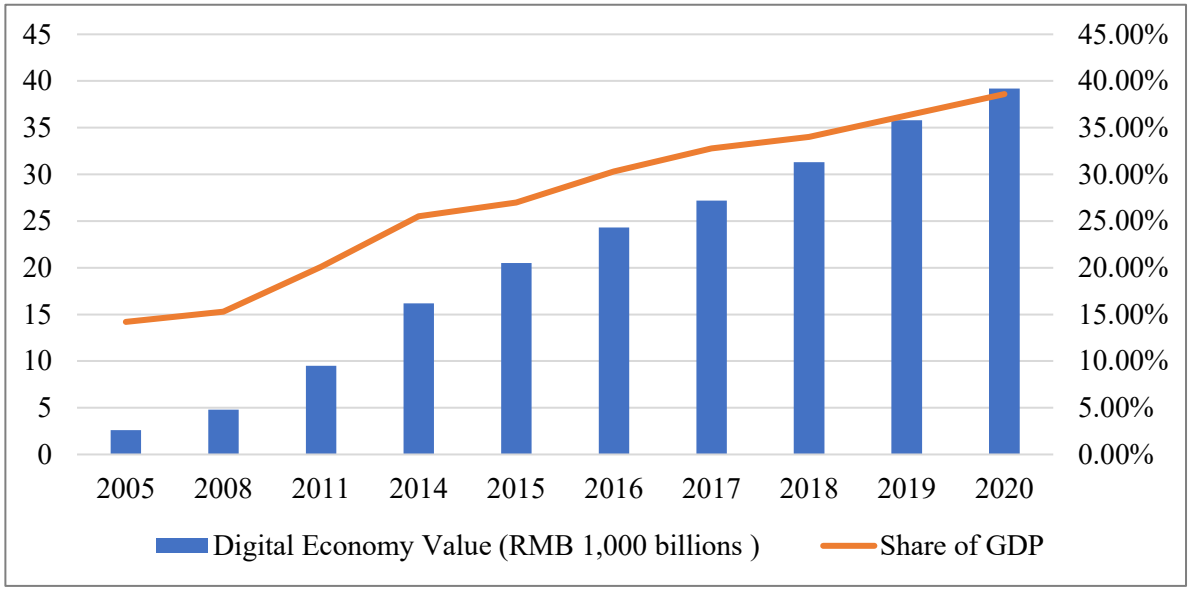
China, often hailed as the 'world factory' in GVCs, has quickly responded to the challenges posed by the digital era. To enhance the competitiveness of manufacturing firms, many manufacturing firms in China have started integrating with the services sector, a process known as the servicification of manufacturing. This approach allows them to increase the value-added content of their products and services, thereby staying relevant in the evolving global market. As shown in Figure 1, an interesting trend is observed in China's manufacturing exports regarding services content. The domestic services content embodied in these exports, also called domestic servicification, is on the rise. This indicates that Chinese manufacturing firms are increasingly utilising and integrating domestic services within their output. On the other hand, the foreign services content embodied in manufacturing exports, known as foreign servicification, is declining. This suggests that Chinese manufacturers are reducing their reliance on imported service inputs. These trends reflect a strategic shift towards leveraging domestic services capabilities and resources, aligning with the broader objective of enhancing value-added content within China's manufacturing sector. By relying more on domestic services, Chinese firms can strengthen their supply chains, increase efficiency, and foster innovation domestically, further solidifying their position as the world factory and driving sustainable growth in the digital era.

Figure 1: Servicification of Manufacturing in China



Source: OECD. Trade in Value Added (TiVA) database (https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm#access), accessed 16 Oct. 2021. Data compiled by the authors.

Figure 2: The Share of Digital Output in GDP in China



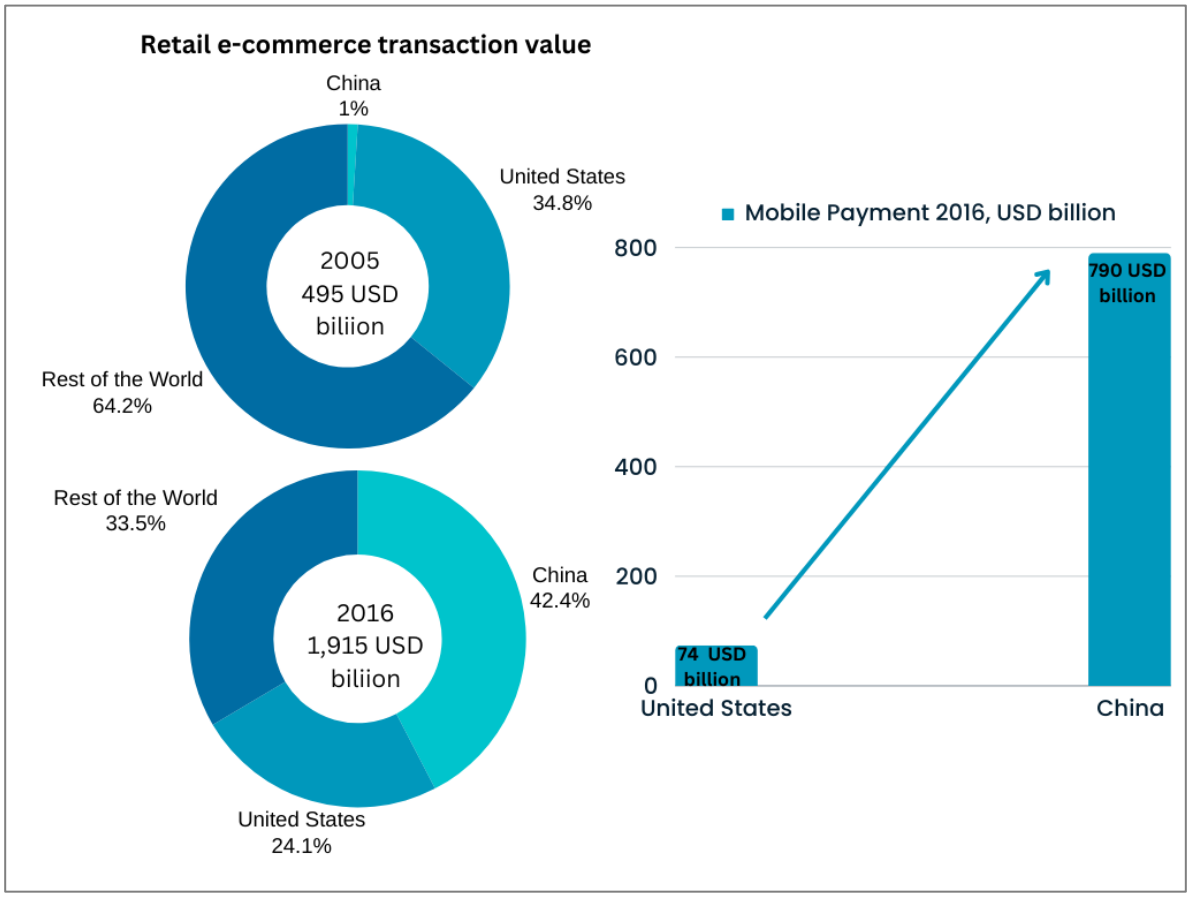
GDP = gross domestic product.

Source: Chinese Statistical Yearbooks; compiled by the authors.

Digitalisation has played a pivotal role in driving economic growth and GVC upgrading in China. Figure 2 illustrates the remarkable growth of the digital sector in China over the past 2 decades. The total output of the digital sector has consistently risen, reaching an impressive RMB 39,200 billion in 2020, which accounted for a significant 38.2% of China's gross

domestic product (GDP). This substantial contribution highlights the profound impact of digitalisation on the Chinese economy.

Figure 3: The Rise of Digital Transactions in the United States and China



Source: PitchBook. Dealogic, e-Market Resource (https://pitchbook.com/data). Accessed 16 Oct. 2021.

Moreover, digital technologies have empowered Chinese manufacturing firms with services, enabling them to enhance their value-added content and competitiveness within GVCs. Through the adoption of digitalisation, these firms gain access to advanced tools that facilitate the seamless integration of services. Automation, data analytics, the Internet of Things (IoT), and artificial intelligence (AI) optimise production processes, drive efficiency improvements, and enable tailored services. Moreover, digitalisation has fuelled the emergence of innovative business models such as e-commerce and digital marketplaces, fostering solid connections between domestic service providers and manufacturers. Figure 3 shows China's dominance in retail e-commerce transactions is evident, with a 42.4% share of

the global value in 2016, surpassing the United States (US) at 33.5%. The country also dominates in mobile payments, with US$790 billion in transactions compared with just US$74 billion in the United States. The widespread adoption of e-commerce and mobile payments has driven growth in domestic service industries and expanded service options within local ecosystems. Additionally, digital platforms facilitate closer collaboration between manufacturers and service providers, strengthening global value chains and resulting in high product quality and improved customer experiences.

3. Data and Measurement

3.1. Data

The data used in this paper are derived from three main databases: the China Stock Market & Accounting Research (CSMAR) database, the Chinese Customs dataset, and Chinese cities' statistical yearbooks. These databases provide comprehensive information on various aspects related to the servicification of manufacturing, digitalisation, and relevant control variables at the firm and city levels.

The CSMAR database covers data of all listed companies on the Chinese stock market, including financial statements and information on the corporate governance of Chinese listed firms. The dataset spans from 2007 to 2018, providing a rich source of information for analysing the servicification and digitalisation measurements. By analysing the income sources of the listed firms, we can identify the extent of services-related incomes and integrate them into the measurement of servicification. leveraging By text mining the annual financial reports, we collect the number of texts related to digitalisation and construct the measurement of digitalisation at the firm level.

The Chinese Customs dataset encompasses transactional-level trade data of all Chinese firms. This dataset is crucial for identifying the listed firms' performance within GVCs. By examining the trade patterns and analysing the extent of their involvement in international trade, we can assess the level of integration within GVCs for these firms, which are crucial in understanding the relationship between digitalisation, servicification, and the firms' position in GVCs.

To account for city-level control variables, we rely on Chinese cities' statistical yearbooks. These yearbooks provide a wide range of data at the city level, including variables such as GDP per capita, education investment, and other socioeconomic indicators. Incorporating these control variables allows us to control for regional variations and capture the impact of local economic conditions on digitalisation, servicification, and GVC performance of manufacturing firms.

3.2. The Measurement of Servicification of Manufacturing Firms

The measurement of servicification of manufacturing firms can be approached from two perspectives: the input approach and the output approach.

In the input approach, servicification is measured by identifying the service inputs used by manufacturing firms and determining the share of service inputs in the total inputs. Service inputs refer to the various services that manufacturing firms utilise in their production processes, such as logistics, marketing, research and development, and after-sales support. By quantifying the proportion of service inputs in the overall inputs, we can gauge the extent to which manufacturing firms rely on services to enhance their production capabilities and value added content.

In the output approach, servicification is measured by focusing on the services income generated by manufacturing firms. This approach involves identifying the income derived from services-related activities, such as maintenance services, consulting services, or software support. By calculating the share of services income in the total income of manufacturing firms, we can assess the level of integration of services into their revenue streams. This measurement provides insights into how manufacturing firms have diversified their business activities to encompass services provision, thereby increasing their value added content.

Both the input and output approaches provide complementary perspectives on servicification, capturing different aspects of the relationship between manufacturing and services. By examining both the share of service inputs and services income, we can obtain a comprehensive understanding of how manufacturing firms engage with services and the extent to which they have transformed into services-oriented entities. These measurements

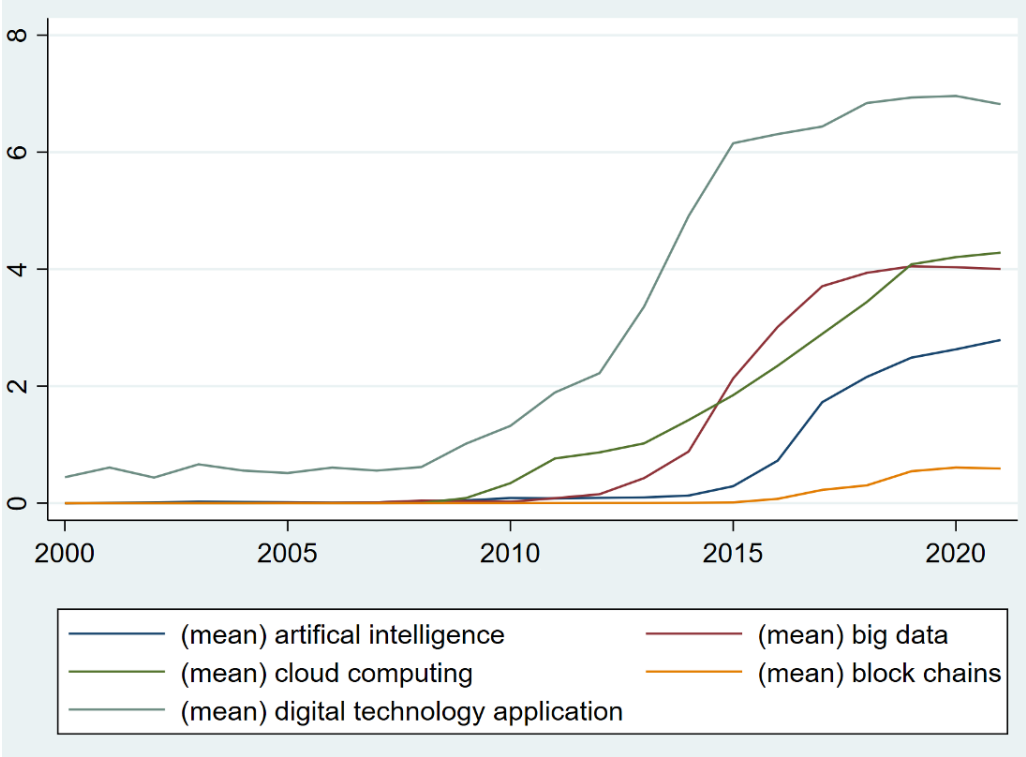
contribute to a deeper analysis of the role of digitalisation and its impact on the servicification process within the manufacturing sector.

3.3. The Measurement of Digitalisation

The measurement of digitalisation in manufacturing firms can be conducted using various indicators that capture different dimensions of digital technology adoption and application. One approach is text mining and analysis, as proposed by Wu et al. (2021). This approach involves extracting relevant information from texts, such as annual reports or other company documents, to identify indicators of digitalisation.

The five dimensions of digitalisation identified in this study are AI, big data, cloud computing technology, blockchain technology, and digital technology application. Within each dimension, specific indicators are considered to assess the level of digitalisation in manufacturing firms. These indicators include 76 specific indicators, such as the presence and extent of artificial intelligence utilisation, the utilisation and analysis of big data, the adoption of cloud computing technology, the integration of blockchain technology into operations, and the application of digital technology in various aspects of the business. Figure 4 shows the five dimensions of digitalisation of Chinese manufacturing firms are increasing, suggesting a rise in digitalisation.

Figure 4: Digitalisation of Chinese-Listed Manufacturing Firms using Text Mining and Analysis



Source:The data is collected from the annual reports of Chinese-listed manufacturing firms.

An alternative indicator of digitalisation is the share of intangible assets related to digital technology in the total asset base of manufacturing firms. This indicator captures the investment in digital assets, such as software, digital platforms, e-commerce shops, and management systems. It reflects the extent to which manufacturing firms have allocated resources to develop and acquire digital technologies that support their operations and enhance their digital capabilities.

By considering these dimensions and indicators, the measurement of digitalisation provides a comprehensive assessment of the level of digital technology adoption and application within manufacturing firms. It allows for a deeper understanding of how firms embrace digitalisation in various aspects of their operations, from data management and analysis to the utilisation of advanced technologies. Such measurements are essential for examining the relationship between digitalisation and the servicification of manufacturing, as well as assessing the impact of digitalisation on firm performance and competitiveness in global value chains.

4. Empirical Specification and Results

4.1. Empirical Model

The model specification for examining the relationship between digitalisation and the servicification of manufacturing can be represented as follows:

$$serv_{ijt} = \beta_1 digit_{ijt} + \beta_2 \boldsymbol{X}_{ijt} + \beta_3 C_{jt} + \delta_i + \delta_t + \varepsilon_{ijt}$$

Where i is the manufacturing listed firms, j is city and t is year. $serv_{ijt}$ represents the servicification level of manufacturing for firm i in city j at time t. This is the dependent variable that captures the extent of servicification of manufacturing firms in China. $digit_{ijt}$ denotes the digitalisation level of firm i in city j at time t, which captures the degree of digital technology adoption and application within the manufacturing firm. $\boldsymbol{X}_{ijt}$ represents a vector of firm-level control variables, such as firm size, age, ownership structure, and investment in research and development. These control variables account for other factors that may affect the servicification level and allow for a more accurate estimation of the effect of digitalisation. C_{jt} represents a vector of city-level control variables, such as the GDP per capita and education investment, which capture the contextual factors at the city level that may affect the servicification level of manufacturing firms. δ_i and δ_t represent the firm and time fixed effects, respectively, which control for unobserved heterogeneity across firms and time-specific factors. ε_{ijt} is the error term. The description of variables and statistical characteristics are shown in Table 1.

Table 1: Variable and Statistical Description

	Variable	N	mean	sd
lnservi_income	log of servicification from income	40576	0.23	0.3
lnservi_cost	log of servicification from cost	40576	0.58	0.22
lndigi1	log of digitalisation index by text-mining	40576	1.05	1.35
lndigi2	log of digitalisation index by intangible asset	40576	2.46	1.3
lntfpop	log of TFP by OP	34273	2.07	0.13
lnemp	log of employment	40507	7.53	1.38
age	firm age	40576	9.14	6.99
lnSale	log of sales	39852	21.17	1.57
size	log of total asset	40574	21.97	1.51
roa	return to asset	40574	0.57	117.26
roe	return on equity	40102	0.02	2.51

TFP = total factor productivity, OP = Olley and Pakes. TFP measured by the Olley and Pakes (1996) approach.

Note: p-values in parentheses; * p<0.1, ** p<0.05, *** p<0.01.

Source: The data are compiled by the authors.

4.2. Baseline Estimation

Table 2 presents the baseline estimation results for the causal relationships between servicification from income (lnservi_income) and digitalisation measures (lndigi1 and lndigi2), controlling for the firm-level and city-level control variables. Column 1 suggests that firms that adopt digital technologies and practices are more likely to generate income from services-related activities. This result is confirmed by the statistically significant and positive coefficient for lndigi1 (digitalisation index by text-mining), indicating that an increase in digitalisation is associated with a higher level of servicification from income. Column 2 introduces firm fixed effects, and the coefficient for lndigi1 remains significant and positive, reinforcing the finding that digitalisation positively affects servicification from income. Including the fixed effects helps control for unobserved heterogeneity across firms that may affect the outcome variable.

In Column 3, we include the firm-level characteristics such as lntfpop (TFP by OP),

lnemp (employment), age (firm age), lnSale (log of sales), size (log of total assets), roa (return to assets), and roe (return on equity) as control variables. The coefficient of digitalisation on servicification remains statistically significant and consistent with the previous models, indicating that the relationship between digitalisation and servicification from income holds even after controlling for firm-level characteristics. We also find that firms with higher total factor productivity (TFP), sales, firm size, and return on assets are associated with a higher level of servicification from income.

Table 2: Baseline Estimation

	(1) lnservi_income	(2) lnservi_income	(3) lnservi_income	(4) lnservi_income
lndigi1	0.031***	0.021***	0.020***	0.016***
	(0.000)	(0.000)	(0.000)	(0.000)
lndigi2				0.006**
				(0.024)
Lntfpop			0.485***	0.486***
			(0.000)	(0.000)
lnemp			–0.011	–0.012
			(0.205)	(0.196)
age			–0.008	–0.009
			(0.214)	(0.193)
lnSale			–0.041**	–0.042**
			(0.014)	(0.014)
size			0.029***	0.028***
			(0.000)	(0.000)
roa			–0.046**	–0.047**
			(0.028)	(0.025)
roe			–0.001***	–0.001***
			(0.002)	(0.002)
Firm FE	No	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes
N	40576	40576	34178	34178
r2	0.030	0.035	0.056	0.056

FE = fixed effect.

Note: p-values in parentheses; * p<0.1, ** p<0.05, *** p<0.01.

Source: The results are regressed and reported by the authors.

Column 4 further includes lndigi2 (digitalisation index by intangible asset) as an additional measure of digitalisation. The coefficient for lndigi2 is statistically significant and positive (0.006**), indicating that a higher level of digitalisation measured by intangible assets is associated with increased servicification from income. This suggests that Chinese manufacturing firms with more intangible digital technologies assets are more likely to engage in services-oriented activities.

Overall, the baseline estimation results in Table 2 provide evidence that digitalisation, as measured by both text-mining and intangible assets, has a positive and significant impact on servicification from income in Chinese manufacturing firms. These findings suggest that adopting digital technologies and leveraging intangible assets related to digitalisation can enhance the integration of services within the manufacturing sector.

4.3. Possible Mechanisms

This section investigates how digitalisation affects the servicification of manufacturing. In Table 3, we highlight that digital technology is a possible mechanism through which digitalisation contributes to the expansion of services within manufacturing firms. The improvement in technology is measured by the TFP by Olley and Pakes (2003). To explore this, we include the interaction between digitalisation and the TFP in the model to investigate whether digitalisation affects servicification via adjusting productivity. As shown in Column 1, the coefficient of the interaction term c.lndigi1#c.lntfpop is positive and weakly significant, suggesting that the impacts of digitalisation on the servicification of manufacturing are enhanced by productivity improvement.

In Column 2, we use an alternative approach by Levison et al.(2003) to measure productivity. The coefficient of the interaction term c.lndigi1#c.lntfplp becomes statistically significant and positive, suggesting manufacturing firms with higher levels of digitalisation and the TFP by Olley and Pakes (1996) are more likely to experience an increase in servicification after digitalisation.

Column 3 and Column 4 further include the alternative indicator of digitalisation (digitalisation index by intangible asset) in the estimation. The interaction term remains

positive and statistically significant in both columns, suggesting manufacturing firms that effectively leverage digital technologies and exhibit high levels of TFP are more capable of expanding their services offerings and capitalising on the opportunities provided by new technologies. These results suggest that manufacturing firms can harness the potential of new technologies and position themselves for greater servicification, thereby enhancing their competitiveness and performance in the evolving business landscape (Acemoglu and Restrepo, 2020).

Table 3: Possible Mechanism: Technology Effect

	(1)	(2)	(3)	(4)
	lnservi_income	**lnservi_income**	**lnservi_income**	**lnservi_income**
lndigi1	–0.040	–0.034	–0.072**	–0.082**
	(0.243)	(0.355)	(0.030)	(0.018)
lndigi2			0.006**	0.007**
			(0.021)	(0.012)
lntfpop	0.223***		0.499***	
	(0.000)		(0.000)	
c.lndigi1#c.lntfpop	0.028*		0.042***	
	(0.090)		(0.009)	
lntfplp		0.229***		0.964***
		(0.000)		(0.000)
c.lndigi1#c.lntfplp		0.024		0.044***
		(0.160)		(0.006)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.043	0.042	0.058	0.074
Obs	34,273	34,273	34,178	34,178

FE = fixed effect.

Note: p-values in parentheses; * p<0.1, ** p<0.05, *** p<0.01.

Source: The results are regressed and reported by the authors.

Another possible channel through which digitalisation affects servicification of manufacturing sectors is profitability. A good example is IBM, which rapidly transitioned from manufacturing to services to adapt to the digital landscape and maintain its profitability in the high-tech sector (Ahamed, Kamoshida, and Inohara, 2013). As depicted in Table 4, the profit effect suggests that firms are driven by the potential profitability of services-oriented activities and adjust their business models accordingly to capture the opportunities presented by digitalisation.

To capture the potential mechanism of the profit effect on servicification, we include the interactions between digitalisation (measured by lndigi1) with return on equity (lnroe) and return on assets (lnroa) to examine whether digitalisation affects the profitability of manufacturing firms which further promotes them to produce more services.

Table 4: Possible Mechanism: Profit Effect

	(1)	**(2)**	**(3)**	**(4)**
	lnservi_income	**lnservi_income**	**lnservi_income**	**lnservi_income**
lndigi1	0.028***	0.022***	0.026***	0.023***
	(0.000)	(0.000)	(0.000)	(0.000)
lndigi2			0.006**	0.006**
			(0.031)	(0.029)
lnroa	–0.001		–0.004	
	(0.756)		(0.142)	
c.lndigi1#c.lnroa	0.002		0.003**	
	(0.103)		(0.021)	
lnroe		0.005***		0.005**
		(0.007)		(0.040)
c.lndigi1#c.lnroe		0.001		0.003**
		(0.478)		(0.039)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
R-squared	0.032	0.031	0.052	0.053
Obs	36,160	36,012	30,548	30,548

FE = fixed effect.

Note: p-values in parentheses; * p<0.1, ** p<0.05, *** p<0.01.

Source: The results are regressed and reported by the authors.

As shown in Column 1 and Column 2, the coefficient of the interaction terms c.lndigi1#c.lnroa and c.lndigi1#c.lnroe are positive but not statistically significant, suggesting the joint effect of digitalisation and profitability may have a limited impact on servicification from income in this model. However, we include the alternative indicator of digitalisation in Column 3, and the coefficient of the interaction term c.lndigi1#c.lnroa is statistically significant and positive, indicating that manufacturing firms with higher levels of digitalisation and greater returns on assets are more likely to experience an increase in servicification, potentially driven by adjustments in their profitability. In Column 4, the coefficient of c.lndigi1#c.lnroa remains statistically significant and positive after controlling for both indicators of digitalisation, suggesting the interaction between digitalisation and return on assets plays an important role in driving servicification from income.

Overall, Table 4 underscores the significance of digitalisation and profitability indicators in shaping the servicification strategies of manufacturing firms. Firms that embrace digital transformation and achieve higher returns on assets are more likely to prioritise services as a profitable avenue, driving the evolution of their business models in response to the opportunities presented by the digital landscape.

5. Conclusion

This paper examines the relationship between digitalisation, profitability, and servicification in manufacturing firms. The study provides valuable insights into how digitalisation and profitability indicators influence the shift towards services-oriented activities by analysing a comprehensive dataset and employing text mining and analysis.

The findings highlight the significant role of digitalisation in driving servicification. Firms with higher levels of digitalisation are more likely to engage in services provision as they leverage new technologies, embrace digital platforms, and adapt their business models to capture the opportunities presented by the digital world. Moreover, the paper emphasises the importance of technology and profitability in influencing the servicification strategies of manufacturing firms. Digitalisation improves firms' technology levels, enabling them to produce more service output and increase the level of servicification. Moreover, higher

profitability levels, driven by digitalisation, motivate firms to shift their focus towards services. This profit-driven approach highlights the potential for manufacturing firms to tap into the profitability advantages that services offer in the digital era.

In conclusion, this paper sheds light on the interplay between digitalisation, profitability, and servicification in the manufacturing industry. The findings emphasise the transformative power of digital technologies and the profit-driven motivations behind the shift towards services-oriented activities. By understanding and harnessing the potential of digitalisation, manufacturing firms can navigate the evolving business landscape, unlock new revenue streams, and capitalise on the profitability advantages offered by the services sector.

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