doi: 10.36689/uhk/hed/2022-01-082

The Impact of Input Digitalization on the Upgrading of the Global Value Chain of Manufacturing Industry

Jue WANG and Ying LIU*

School of Economics and Management, Northwest University, Xi'an, China; wjueba@126.com; m17691153179@163.com

* Corresponding author: m17691153179@163.com

Abstract: The development of the digital economy has made the input of digital elements an important factor affecting the upgrading of the global value chain of the manufacturing industry. Based on the WIOD database, this paper measures the Input digitalization index of the manufacturing industry in 42 economies, and then conducts an empirical analysis of the impact of input digitalization on the upgrading of manufacturing GVCs. The results show that input digitalization has a significant positive effect on the GVC participation index and GVC status index of the manufacturing industry, and the effect of digital infrastructure is the most significant; In addition, there are significant differences in the influence of input digitalization from domestic and foreign sources on the GVC index. The research conclusions provide transnational evidence and decision-making reference for promoting the digital transformation of input in manufacturing industry and achieving the goal of climbing to the high-end of GVC.

Keywords: input digitalization; global value chain; manufacturing industry

JEL Classification: C33; C67; F14

1. Introduction

In the era of digital economy, data, as a new "bulk commodity", has accelerated its integration with various industries by means of data mining, data flow, and data sharing, and has played an important role in reconstructing the division of labor and governance patterns in the global value chain (Qiu et al., 2021). The United Nations Industrial Development Organization pointed out in the "2022 Industrial Development Report" that the application of advanced digital manufacturing technology is of great benefit to enhancing economic resilience, emphasizing that countries around the world must improve their manufacturing digital capabilities to cope with an extremely uncertain future. Data is an important basis and prerequisite for the rise of the digital economy, and the input of digital elements is becoming an important factor in determining productivity, promoting the continuous refinement of the international division of production, and driving the upgrade of the global value chain (Goldfarb & Tucker, 2012). Therefore, under the background that the integrated development of the digital economy and the manufacturing industry has become the mainstream trend of global economic development, accurately identifying the global value chain upgrading effect of manufacturing digital elements can provide empirical evidence and policy reference for promoting the digital transformation of the manufacturing industry, boosting high-quality development, and promoting the upgrading of the global value chain from the perspective of industrial integration.

Global value chain is the current research hotspot in the field of international economics. Existing domestic literature discusses the influence of factors such as manufacturing servitization (Liu et al., 2016), market size (Dai et al., 2017), and factor allocation structure (Li, 2015) on the upgrading of global value chains. With the strong rise of the digital economy, the global value chain upgrade effect of "digital transformation" has become the focus of scholars' attention. The related literature is mainly divided into two branches: one is the theoretical discussion on the effect of digitalization. Jing and Yuan (2019) believes that the digital wave is setting off a new direction that drives the upgrading of the global value chain. Qiu and Guo (2019) believes that the digital economy has become an important driving force for the upgrading of the value chain of small and medium-sized enterprises by means of cost saving, value creation, and value chain governance. Yu (2021) proposed the concept of digital economy value chain. It is believed that data elements make production increasingly refined and change the distribution method of the traditional value chain; at the same time, the adaptation of the platform economy to the manufacturing end makes the global value chain present a structural remodeling. The second is an empirical test on the effect of digitalization. Qi and Ren (2022) constructed an industry-level digital economy penetration indicator, using cross-country panel data to find that digital economy penetration has significantly improved the industry upstreamness of the GVC. Zhang and Yu (2020) used the domestic value-added rate of exports of Chinese manufacturing enterprises as an indicator to test the effect of input digitalization on upgrading the value chain of enterprises at the micro level. Zhang and Yu (2021) added a re-examination to identify the sources of digital element input. He (2020) uses data from China's manufacturing industry to verify the significant improvement of digital input in global value chain participation. Zhang et al. (2022) examined the driving effect of the digital economy based on the depth and breadth of the global value chain. Existing literature provides a wealth of references for this study.

Accurately defining the concept of " input digitalization " is the premise of this study. The concept of input digitalization first appeared in the White Paper on the Development of China's Digital Economy (2017). Referring to Zhang and Yu (2020), this paper defines input digitalization as a process of digital transformation that uses digital infrastructure, digital media and digital transactions and other "data elements" to promote economic structure optimization and efficiency improvement. Based on the above conceptual definitions, the following paper attempts to use country-industry-level data from a cross-country perspective to study the influence of manufacturing input digitalization on GVC upgrades, that is, to assess the degree to which downstream manufacturing producers are affected by the digital sector in the production process.

2. Methodology

2.1. Model Settings

Combined with existing research, this paper sets the following benchmark model:

$$GVC_{cit} = \beta_0 + \beta_1 Dig_{cit} + \beta_2 X_{cit} + \phi_c + \phi_i + \phi_t + \varepsilon_{cit} \tag{1}$$

Among them, the subscripts c、i、t represent the country, industry and year in turn; GVC_{cit} represent the GVC participation index and GVC position index of the i industry in the c country during the t period; Dig_{cit} represents the input digitalization level of the i industry in the c country during the t period; X_{cit} are the control variables of the model; ϕ_c、ϕ_i、ϕ_t are the country, industry and time fixed effects in sequence; ε_{cit} are the random error terms.

2.2. Variable Description

1. Input Digitalization: Referring to Zhang and Yu (2020) screening and definition of digital element industries, this article lists the connotations of major digital elements and their supporting industries based on ISIC Rev4.0 one by one (see Table 1). For the wholesale sector (G-46), retail trade sector (G-47) and publishing sector (J-58), which only partially belong to the digital sector, the split coefficient method was introduced to obtain an input-output system covering 59 sectors. The split weights of G-46 and G-47 are calculated based on the share of online trade agency and internet wholesale revenue in the main business revenue of the wholesale sector and the share of Internet retail revenue in the retail sector's main business revenue. The data comes from the "China Economic Census Yearbook"; J-58 is divided according to the proportion of the sales amount of "electronic publications", "audio-visual products" and "non-publication products" to the total sales amount of the publishing department. The original data comes from the "Guoyanwang" database. Since the proportion of digitalization in the above three departments is relatively small in each country, considering the availability of data, the split coefficients of other countries are also replaced by China's.

Table 1. The connotations of major digital factors and their supporting industries based on ISIC Rev4.0 (Zhang & Yu, 2020)

the Core Elements	Connotation	Supporting Industries
Digital Infrastructure	Telecommunications Equipment and Services	J-61 J-62 J-63
	Computer Software	
	Computer Hardware	C-26
Digital Media	Web Publishing and Distribution	J-58：5820 Distribution of software
	Webcast	J-59 J-60
	Data Streaming Service	
Digital Transaction	Web Agency and Wholesale	G-46：Online trade agency, Internet wholesale G-47：Internet retail
	Internet Retail	

Drawing on the measurement method of "Input Servitization", the input-output method is used to calculate the "direct and complete consumption coefficient" of the manufacturing industry for the supporting industry of digital elements. Further, referring to Yang (2015), the relative indicator "direct and complete dependence" was introduced to measure the level of input digitalization in the manufacturing industry. The "direct consumption coefficient" a_{ij} reflects the production technology structure of the national economy, which is expressed by the value of the products of the i sector consumed per unit of output value of the j sector: $a_{ij} = \frac{q_{ij}}{Q_j}$. q_{ij} is the input value by department i to department j, and Q_j is the total input value of department j. However, considering the indirect economic and technological links between various sectors, a complete consumption coefficient b_{ij} is introduced to fully characterize the input of sector i to sector j through industrial linkage effects. That is, $b_{ij} = a_{ij} + \sum_{m=1}^{N} a_{im}a_{mj} + \sum_{d=1}^{N}\sum_{m=1}^{N} a_{id}a_{dm}a_{mj} + \cdots$, the second term on the right side of the equation is the first round of indirect consumption of the i department through the m department by the j department. Similarly, the third term is the second round of indirect consumption, and so on. Assuming that the direct consumption coefficient matrix A is obtained by using the input-output method, the complete consumption coefficient matrix $B = A + A^2 + A^3 + A^4 + \cdots + A^k + \cdots$ is easy to obtain through matrix operations $B = (I - A)^{-1} - I$, where I is the unit matrix. The above absolute indicators are difficult to reflect the relative importance of digital input in total input, so "the degree of direct and complete dependence" is introduced to measure the proportion of the consumption of the manufacturing industry to the supporting industry of digital elements to all consumption. a_{dj} is the direct consumption coefficient of the manufacturing industry to the supporting industry of digital elements, b_{dj} is the complete consumption coefficient of the manufacturing industry to the supporting industry of digital elements, a_{kj} is the direct consumption coefficient of the manufacturing industry to any industry, and b_{kj} is the complete consumption coefficient of the manufacturing industry to any industry. The calculation formulas of the degree of direct dependence and the degree of complete dependence are: $Dig^{direct} = \Sigma_d a_{dj} \,/\, \Sigma_{k=1}^{N} a_{kj}$ and $Dig^{complete} = \Sigma_d b_{dj} \,/\, \Sigma_{k=1}^{N} b_{kj}$. In this paper, $Dig^{complete}$ is used for benchmark regression, and Dig^{direct} is used for robustness test.

2. GVC Index: The decomposition of the total export added value based on the input-output model is the premise of realizing the macro-measurement research on the division of labor in the global value chain (Ni, 2018). Based on the decomposition of Koopman (2014), this paper draws on the method of Huang et al. (2018), and selects the corresponding indicators of the TIVA database for the following calculation.

- Using the GVC position index proposed by Koopman et al. (2010) to measure the position in the global value chain division of labor of a country's manufacturing industry:

$$GVC_{cit}^{pos} = ln\left(1 + \frac{IV}{E}\right) - ln\left(1 + \frac{FV}{E}\right) \quad (2)$$

- Considering that there may be situations where the GVC position index is equal, but the degree of participation is widely different, Koopman et al. (2010) propose a GVC participation index as a supplement:

$$GVC_{cit}^{par} = \frac{IV}{E} + \frac{FV}{E} \quad (3)$$

- The larger the GVC_{cit}^{pos}, the higher the status of the international division of labor, the closer the industry in the country is to the upstream of the GVC division of labor system, and the higher added value is obtained by providing intermediate products to other economies (Wang et al., 2013). Similarly, the larger the GVC_{cit}^{par}, the deeper its involvement in the global value chain.

3. Control Variable: Control variables were selected by referring to relevant literature and considering data availability. Industry size (IS): expressed in terms of total industry output; Industry output per capita (OPH): expressed by the ratio of the total output of each industry to the number of employees in each industry; Industry capital output ratio (CO): expressed as the ratio of industry fixed capital stock to industry total output; Industry capital labor ratio (CL): expressed as the ratio of industry fixed capital stock to industry labor force; Foreign direct investment (FDI): expressed as a proportion of foreign direct investment flows to GDP; Labor Productivity (LP): expressed using constant 2010 per capita national income. In order to reduce the heteroscedasticity and multicollinearity between the data, this paper takes the natural logarithm of the above control variables when building the model. Economic Freedom (EFI): an indicator that combines data on a country's tax rate system, legal system, trade openness, government efficiency, etc.

2.3. Data Sources and Data Processing

This paper selects the world input-output table, which reflects the input-output connection between different countries and industries, to measure the input digitalization indicators at the cross-country-industry level. At the same time, considering the practical significance of the research in this paper and the matching problem with other databases, the largest and latest common divisor of the time span, that is, 2000-2014, is selected as the time range of the sample. The original data of input digitization comes from WIOD (2016); the original data of GVC index comes from the ICIO database of OECD; the labor productivity and FDI data come from the World Bank; the EFI data comes from the Fraser Institute database; The rest of the control variable data are derived from the Socio-Economic Accounts (WIOD-SEA) in the World Input-Output Database.

It should be pointed out that, first, WIOD (2016) contains 44 countries (regions), but TWN (Taiwan, China) and ROW (the rest of the world) lack some data of control variables, so they are excluded. The total number of economies in the sample is 42, and the total number of manufacturing industries is 16. There is a total of 19 manufacturing industries under ISIC Rev4.0, which are integrated into the following 16 industries according to the research needs of this paper: C10-C12; C13-C15; C16; C17&C18; C19; C20&C21; C22; C23; C24; C25; C26; C27; C28; C29; C30; C31-C32&C33. The structure of the regression data in this paper is the three-dimensional level of "country- industry - year", so the number of observations in this paper is 10,080 (= 42 × 16 × 15). Second, the industry classification standards of the WIOD and ICIO databases are slightly different. This paper integrates the two definition standards and manually matches to obtain the multinational panel data of 16 industries. The descriptive statistical characteristics of the main variables are shown in Table 2.

Table 2. Basic statistical characteristics of each variable

Variable name	Variable meaning	Observations	Mean	Standard deviation	Minimum	Maximum
GVC_{par}	GVC participation index	10,080	0.633	0.102	0	0.970
GVC_{pos}	GVC status index	10,080	-0.006	0.167	-0.572	0.490
Dig	Input digitalization	10,080	0.068	0.071	0	0.578
$\ln CL$	Natural logarithm of industry capital labor ratio	10,002	5.447	2.213	0.083	14.264
$\ln CO$	Natural logarithm of industry capital-output ratio	10,003	-0.629	0.701	-5.497	2.760
$\ln IS$	Natural logarithm of industry size	10,015	9.860	3.410	-2.303	21.429
$\ln OPH$	Natural logarithm of output per industry	10,015	6.151	2.222	1.792	16.539
$\ln LP$	Natural logarithm of labor productivity	10,080	9.883	0.969	6.630	11.566
$\ln FDI$	Natural logarithm of foreign direct investment	9,552	1.195	1.397	-6.523	6.107
EFI	Economic freedom	10,080	7.473	0.670	5.180	8.770

3. Results

3.1. Benchmark Regression

Table 3 reports the benchmark regression results. After Hausman test, we select the fixed effect model for empirical analysis. Columns (1) and (4) only add core explanatory variables and control individual fixed effects. The results show that the regression coefficient of Dig is significantly positive at the 1% level. Columns (2) and (5) gradually added control variables, and introduced individual and time dummy variables. The coefficients and significance of the core explanatory variables did not change fundamentally. Columns (3) and (6) add control variables and introduce industry-level clustering robust standard errors on the basis of columns (2) and (5). The coefficient of Dig is still positive at the 1% significance level. This result shows that input digitization is conducive to improving the GVC participation index and GVC position index, that is, effectively driving the upgrading of the global value chain.

Table 3. Benchmark regression results

	(1) GVC_{par}	(2) GVC_{par}	(3) GVC_{par}	(4) GVC_{pos}	(5) GVC_{pos}	(6) GVC_{pos}
Dig	0.218 ***	0.207 ***	0.174 ***	0.237 ***	0.196 ***	0.241 ***
	(4.97)	(4.95)	(3.96)	(4.89)	(4.74)	(5.39)
$\ln CL$		-0.0496 ***	-0.0517 ***		0.0522	0.0661
		(-8.14)	(-8.43)		(1.36)	(1.56)
$\ln CO$		0.0141**	0.0184***		-0.0427	-0.0569*
		(2.19)	(2.87)		(-1.50)	(-2.00)
$\ln IS$		0.00955***	0.0234***		-0.0420**	-0.0744***
		(3.98)	(8.68)		(-2.61)	(-3.74)
$\ln OPH$		0.0550***	0.0572***		-0.0393**	-0.0464
		(9.10)	(9.47)		(-2.49)	(-0.94)
$\ln LP$			-0.0933 ***			0.260 ***
			(-12.71)			(4.42)
$\ln FDI$			0.00192 **			-0.00373
			(2.44)			(-1.55)
EFI			0.0137 ***			-0.0300
			(5.07)			(-1.47)
Cons	0.618 ***	0.474 ***	1.150 ***	0.383 ***	0.723 ***	-1.335 ***
	(203.42)	(30.00)	(20.22)	(10.76)	(4.52)	(-3.13)
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
N	10,080	10,002	9,478	10,080	10,002	9,478
R^2	0.00261	0.0778	0.101	0.0647	0.0936	0.107

Note: Values of t-statistics are in parentheses, and * p < 0.1, ** p < 0.05, *** p < 0.01.

Table 4. Replacement indicators and endogeneity problems

	(1) GVC_{par}	(2) GVC_{pos}	(3) GVC_{par}	(4) GVC_{pos}	(5) GVC_{par}	(6) GVC_{pos}	(7) GVC_{par}	(8) GVC_{pos}
Dig			0.0330***	0.178***	0.139***	0.191***	0.0937***	0.368***
			(13.11)	(27.82)	(6.29)	(18.61)	(2.62)	(8.44)
$L.Dig$	0.254***	0.143***						
	(5.56)	(14.05)						
$\ln CL$	-0.0511***	0.0459***	0.0146**	-0.0943***	0.00874	0.0113	-0.0510***	0.0660***
	(-8.12)	(2.77)	(2.54)	(-6.46)	(1.60)	(0.86)	(-8.31)	(3.28)
$\ln CO$	0.0162**	-0.0433**	-0.0352***	0.115***	-0.0282***	0.0130	0.0181***	-0.0809***
	(2.47)	(-2.49)	(-6.07)	(7.80)	(-5.22)	(1.01)	(2.82)	(-3.96)
$\ln IS$	0.0248***	-0.0706***	0.00687***	0.0339***	0.00572***	-0.0114***	0.0238***	-0.0863***
	(8.61)	(-9.28)	(11.50)	(22.31)	(5.02)	(-4.19)	(8.86)	(-11.46)
$\ln OPH$	0.0558***	-0.0446***	-0.0185***	0.0557***	0.0172***	-0.0155	0.0562***	-0.0525***
	(9.08)	(-2.75)	(-3.31)	(3.93)	(3.23)	(-1.21)	(9.31)	(-2.79)
$\ln LP$	-0.0908***	0.218***	-0.0133***	0.0411***	-0.106***	0.183***	-0.0946***	0.180***
	(-11.56)	(10.44)	(-9.12)	(11.06)	(-14.35)	(10.38)	(-12.91)	(9.13)
$\ln FDI$	0.00133	-0.00980***	0.00559***	-0.0140***	-0.00110	-0.00176	0.00106*	-0.00747***
	(1.31)	(-3.65)	(7.83)	(-7.73)	(-1.42)	(-0.95)	(1.78)	(-2.84)
EFI	0.0120 ***	-0.0477 ***	-0.00381 *	0.0144 ***	0.0112 ***	-0.0357 ***	0.0149 ***	-0.0205 ***
	(3.98)	(-6.06)	(-1.85)	(2.74)	(3.16)	(-4.22)	(5.57)	(-2.89)
Cons	1.128 ***	-0.699 ***	0.707 ***	-0.161 ***	1.362 ***	-0.967 ***	1.159 ***	-0.632 ***
	(18.57)	(-4.06)	(58.73)	(-5.27)	(23.65)	(-7.02)	(20.42)	(-4.01)
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	8,857	8,857	9,478	9,478	9,478	9,478	9,478	9,478

Note: Values of t-statistics are in parentheses, and * p < 0.1, ** p < 0.05, *** p < 0.01.

3.2. Robustness Check

- Endogeneity

First, considering that there may be a time lag in the input digitalization effect discussed in this paper, and in order to ensure the causal relationship to a certain extent, the input digitalization index with a lag period of one period is selected to re-regress. The results are shown in columns (1) and (2) of Table 4, which confirms the driving effect of input digitalization on the upgrading of the global value chain of manufacturing. Secondly, for the estimation bias caused by omitted variables, refer to Bai (2009) to add interactive fixed effects to control the heterogeneity of multidimensional shocks. Columns (3) and (4) of Table 4 control the industry fixed effect, the year fixed effect and the industry-year one-dimensional interactive fixed effect. Columns (5) and (6) control the country fixed effect, the industry fixed effect, and the country-industry one-dimensional interaction fixed effect. The results show that the sign and significance of the core explanatory variable coefficients are completely consistent with the benchmark regression, and the previous conclusions are robust.

Table 5. Split the indicator of the core explanatory variable

	(1) GVC_{par}	(2) GVC_{par}	(3) GVC_{par}	(4) GVC_{pos}	(5) GVC_{pos}	(6) GVC_{pos}
Dig^I	0.175***			0.0706***		
	(4.01)			(3.10)		
Dig^M		0.00214			0.0105	
		(0.38)			(1.54)	
Dig^D			0.115			0.415
			(0.39)			(1.18)
$\ln CL$	-0.0439***	-0.0444***	-0.0446***	0.0399***	0.0405***	0.0396***
	(-5.82)	(-5.88)	(-5.90)	(5.43)	(5.50)	(5.37)
$\ln CO$	0.00928	0.00982	0.00987	-0.00783	-0.00830	-0.00784
	(1.21)	(1.28)	(1.29)	(-1.02)	(-1.08)	(-1.02)
$\ln IS$	0.0234***	0.0237***	0.0237***	-0.0185***	-0.0183***	-0.0183***
	(8.30)	(8.42)	(8.42)	(-5.73)	(-5.68)	(-5.66)
$\ln OPH$	0.0499***	0.0499***	0.0501***	-0.0525***	-0.0532***	-0.0524***
	(7.06)	(7.06)	(7.07)	(-7.25)	(-7.35)	(-7.22)
$\ln LP$	-0.0935***	-0.0946***	-0.0947***	0.176***	0.176***	0.176***
	(-12.67)	(-12.81)	(-12.81)	(20.05)	(19.98)	(19.95)
$\ln FDI$	0.00104 *	0.00107 *	0.00106 *	0.00218 **	0.00217 **	0.00210 **
	(1.74)	(1.79)	(1.77)	(2.31)	(2.29)	(2.22)
EFI	0.0137 ***	0.0150 ***	0.0150 ***	-0.00662 **	-0.00633 **	-0.00630 **
	(5.11)	(5.60)	(5.60)	(-2.07)	(-1.97)	(-1.96)
Cons	1.152 ***	1.162 ***	1.162 ***	-1.405 ***	-1.396 ***	-1.396 ***
	(20.24)	(20.41)	(20.41)	(-20.64)	(-20.49)	(-20.51)
FE	Yes	Yes	Yes	Yes	Yes	Yes
N	9,478	9,478	9,478	9,478	9,478	9,478
R^2	0.0999	0.0983	0.0983	0.104	0.104	0.104

Note: In Table 5, Dig^I, Dig^M, and Dig^D represent digital infrastructure, digital media, and digital transactions in sequence.

- Replacement Index

The input digitalization level was remeasured using Dig^{direct} to replace the core explanatory variables. As shown in column (7) and column (8) in Table 4, the sign and significance of the core explanatory variables have not changed, which further confirms the core conclusion of the previous article.

- Split the Indicator

According to the previous Table 1, the indicator of the core explanatory variable is divided into three types of digital inputs: digital infrastructure, digital media and digital transactions to test the robustness of the benchmark regression results and analyze the different influences of various input digitalization on the upgrading of the manufacturing global value chain.

The estimation results in columns (1) and (4) in Table 5 show that digital infrastructure promotes the improvement of GVC participation index and position index at the 1% significance level. As an important part of input digitalization, the estimated coefficient of $D\mathrm{ig}^{I}$ is significantly positive, which further supports the core conclusion of this paper. The coefficient of Dig in columns (2), (4) and (3), (6) of Table 5 is positive but not significant.

The possible explanations for the above results are: data is a key element of the digital transformation of the manufacturing industry, and digital infrastructure is the fundamental prerequisite for data generation, flow and storage. Its GVC value-added effect and industrial chain integration effect are an important support and guarantee for the GVC upgrading of digital empowerment (Acemoglu & Restrepo, 2019). Digital media and digital transactions must rely on a sound digital infrastructure to play their roles in information flow, resource integration, and cost-plus. In addition, in the sample period of this paper, the former is still in the early stage of development and accounts for a small proportion of the digital inputs in the manufacturing industry, so the statistical results show that its driving effect on the upgrading of the global value chain is not significant.

3.3. Re-examination Based on the Different Input Source

In the context of globalized production, the international division of labor has rapidly expanded into the digital field, and data, as a key production factor, has particularly obvious characteristics of "globalization" and "fragmentation" (Guo & Qiu, 2020). We further divide digital inputs into domestic and foreign sources and re-examine its effect on the GVC upgrading in the manufacturing industry.

Referring to the reported results in Table 6, the GVC_{par} column shows that both domestic and foreign sources of input digitalization significantly improved the GVC participation index. The results of the GVC_{pos} column shows that the input digitalization from domestic sources has significantly improved the GVC_{pos}, while the coefficient of Dig^{for} is significantly negative. It shows that the input digitization from foreign sources not only does not help a country's manufacturing industry to climb the high-end of the GVC, on the contrary reduces its GVC division of labor status.

The possible explanations are: Generally speaking, the input digitalization from domestic sources in the manufacturing industry of each country accounts for an absolute proportion, and the foreign sources is relatively low. Therefore, the input digitalization from domestic sources is likely to promote the GVC upgrading of the manufacturing due to its dominant force and localization advantages. The increase of input digitalization from foreign sources means that intermediate products from other countries will be used in downstream production links for production. Foreign digital factor occupy the first-mover advantage in technology, which will make it easy for them to "squeeze" high profits by virtue of their monopoly position and increase the purchase price of intermediate products in downstream domestic industries (Xu & Xia, 2020); Over-reliance on key high-end elements is not conducive to domestic innovation security, and it is easy to be "stuck in the neck" and hinder the improvement of GVC division of labor status (Zhang & Yu, 2021); At the same time, the input of advanced foreign digital factors may need to be run in with domestic high-skilled labor factors to match, and "acquisition" will cause a time lag, so it will not immediately manifest as an improvement of GVC division of labor status (Wu & Ma, 2020).

Table 6. Test results of re-examination based on the different input source

	GVC_{par}			GVC_{pos}		
Dig^{for}	0.0955 ***		0.0886 ***	-0.134 ***		-0.134 ***
	(3.89)		(3.59)	(-34.00)		(-33.95)
Dig^{dom}		0.101 ***	0.0866 **		0.226 ***	0.201 ***
		(2.93)	(2.51)		(5.52)	(5.22)
$\ln CL$	-0.0440 ***	-0.0443 ***	-0.0439 ***	0.0371***	0.0428***	0.0375***
	(-5.83)	(-5.87)	(-5.82)	(4.37)	(4.75)	(4.41)
$\ln CO$	0.00985	0.00898	0.00904	-0.0169**	-0.0118	-0.0188**
	(1.29)	(1.17)	(1.18)	(-1.97)	(-1.29)	(-2.18)
$\ln IS$	0.0238***	0.0232***	0.0232***	-0.0260***	-0.0204***	-0.0273***
	(8.44)	(8.20)	(8.23)	(-8.19)	(-6.05)	(-8.57)
$\ln OPH$	0.0496***	0.0501***	0.0497***	-0.0449***	-0.0543***	-0.0445***
	(7.01)	(7.09)	(7.04)	(-5.64)	(-6.43)	(-5.61)
$\ln LP$	-0.0952***	-0.0936***	-0.0943 ***	0.146 ***	0.179 ***	0.148 ***
	(-12.90)	(-12.67)	(-12.77)	(17.51)	(20.29)	(17.76)
$\ln FDI$	0.000989 *	0.00106 *	0.000982	0.00243 ***	0.00268 ***	0.00240 ***
	(1.65)	(1.77)	(1.64)	(3.61)	(3.75)	(3.58)
EFI	0.0146 ***	0.0146***	0.0143***	-0.00629**	-0.00725**	-0.00719**
	(5.49)	(5.45)	(5.35)	(-2.10)	(-2.27)	(-2.40)
Cons	1.163***	1.153***	1.155***	-0.973***	-1.420***	-0.992***
	(20.44)	(20.24)	(20.28)	(-14.92)	(-20.85)	(-15.20)
FE	Yes	Yes	Yes	Yes	Yes	Yes
N	9,478	9,478	9,478	9,478	9,478	9,478
R^2	0.0998	0.0992	0.100	0.209	0.108	0.211

Note: Dig^{for} and Dig^{dom} represent input digitalization from foreign sources and from domestic sources in turn.

4. Discussion and Conclusion

China's manufacturing industry has been trapped in the "low-end lock-in" dilemma for a long time, and the strong rise of the digital economy has become an excellent opportunity to climb the middle and high end of the global value chain. This paper uses the manufacturing industry data of 42 economies from 2000 to 2014 to measure the country-industry level of input digitization indicators. Based on this, this paper conducts an empirical analysis on the effect of input digitalization on the upgrading of the global value chain of the manufacturing industry. The main research conclusions are as follows: input digitization significantly promotes the improvement of the GVC participation index and GVC position index of the manufacturing; Splitting the input digitalization indicators shows that the driving effect of digital infrastructure is the most significant, and digital media and digital transactions may need rely on the former to better play its driving effect. This conclusion is consistent with the research conclusion of Zhang and Yu (2020) at the micro-enterprise level. After further analysis, it was found that digital inputs from domestic and foreign sources both contributed to the improvement of the GVC participation index, but digital inputs from foreign sources showed an inhibitory effect on the GVC position index. This conclusion supports the research of Zhang and Yu (2021) to a certain extent.

Compared with the existing literature, the characteristics and innovations of this paper are reflected in the following two aspects: First, the related research on input digitalization measurement is close to blank, and the existing articles are limited to the scope of China's manufacturing industry. This paper measures the input digitalization level of manufacturing industry in 42 countries (regions) included in WIOT, which enriches the data system of existing research. Second, few studies have explored the impact of input digitalization on the upgrading of the global value chain, and some relevant studies have started from micro-enterprises in China's manufacturing industry, and there is a lack of research at the cross-country level. This empirical analysis based on cross-country-industry-level data looks to fill this gap. Needless to say, limited by the availability of data, the time span of empirical research is only 2000-2014. Therefore, we look forward to further research in the future.

This paper's research based on a transnational perspective provides some implications for the development of China manufacturing's input digitalization and related policy formulation. First of all, in the process of participating in the global value chain, it is necessary to pay full attention to the accumulation of data elements, be good at integrating knowledge resources in the upstream and downstream connections, drive the digital and intelligent transformation of the manufacturing industry, and then climb the middle and high-end of the global value chain. Secondly, the matching mechanism between digital infrastructure and other digital inputs should be fully optimized, and a complete and systematic manufacturing digital support system should be built. Finally, rationally treat the impact of input digitalization from foreign sources on the GVC division of labor status, and enhance the ability to use the spillover effect of foreign digital elements to promote the development of the domestic digital industry.

Acknowledgments: This work was supported by the General Project of the National Social Science Fund of China (Grant No. 20BJY090).

Conflict of interest: none

References

Acemoglu, D., & Restrepo, P. (2019). Automation and new tasks: How technology displaces and reinstates labor. *Journal of Economic Perspectives, 33*(2), 3–30. https://doi.org/10.1257/jep.33.2.3

Bai, J. (2009). Panel data models with interactive fixed effects. *Econometrica, 77*(4), 1229–1279. https://doi.org/10.3982/ECTA6135

CAICT. (2017). *The White Paper on the Development of China's Digital Economy*. CAICT. http://www.cac.gov.cn/2017-07/13/c_1121534346.htm

Dai, X., Liu, M., & Zhang, W. (2017). How Does the Expansion of Local Market Induce GVC Upgrading? *Journal of World Economy*, *9*, 27–50.

Goldfarb, A., & Tucker, C. (2019). Digital economics. *Journal of Economic Literature, 57*(1), 3–43. https://doi.org/10.1257/jel.20171452

Guo, Z., & Qiu, Y. (2020). The Reconstruction of Global Value Chains in the Era of Digital Economy: Typical Features, Theoretical Mechanisms and China' s Countermeasures. *Reform, 10*, 73–85.

He, W. (2020). Countermeasures for Digital Economy to Promote the Upgrading of China's Manufacturing Industry under the Visual of Global-Value-Chain. *Asia-pacific Economic Review*, *3*, 115–130. https://doi.org/10.16407/j.cnki.1000-6052.2020.03.013

Huang, G., Wang, J., & Ma, L. (2018). Accounting Research on the Global Value Chain Division of China's Manufacturing Industry. *Journal of Statistics and Information*, *12*, 20–29.

Jing, L., & Yuan, P. (2019). New Trends in Global Value Chain Changes and China's Countermeasures. *Management World*, *11*, 72–79. https://doi.org/10.19744/j.cnki.11-1235/f.2019.0148

Koopman, R., Wang, Z., & Wei, S. J. (2014). Tracing value-added and double counting in gross exports. *American Economic Review, 104*(2), 459–494. https://doi.org/10.1257/aer.104.2.459

Koopman, R., Powers, W., Wang, Z., & Wei, S. J. (2010). *Give credit where credit is due: Tracing value added in global production chains* (No. w16426). National Bureau of Economic Research. https://www.nber.org/system/files/working_papers/w16426/w16426.pdf

Liu, B., Wei, Q., Lv, Y., & Zhu, K. (2019). Servitization of Manufacturing and Value Chain Upgrading. *Economic Research Journal*, *3*, 151–162.

Li, F. (2015). The Status of International Division of Labor under Global Value Chain: An Analysis Based on Added Value. *International Economics and Trade Research*, *9*, 31–42. https://doi.org/10.13687/j.cnki.gjjmts.2015.09.003

Ni, H. (2018). New Progress in the Theory and Application of Global Value Chain Measurement. *Journal of Zhongnan University of Economics and Law*, *3*, 115–126. https://doi.org/10.19639/j.cnki.issn1003-5230.2018.0042

Qi, J., & Ren, Y. (2022). Digital Economy Development, Institutional Quality and Upstreanness of Global Value Chain. *International Economics and Trade Research*, 1, 51–67. https://doi.org/10.13687/j.cnki.gjjmts.20220104.001

Qiu, Y., Yuan, H., & Dai, M. (2021). Study on Innovations on DEPA Digital Trade Rules Promoting the Construction and Evolution of China's Digital Value Chains. *Intertrade*, *12*, 34–42. https://doi.org/10.14114/j.cnki.itrade.2021.12.011

Qiu, Y., & Guo, Z. (2019). Research on the Mechanism and Policy of Digital Economy for Promoting the Upgrading along Global Value Chains of Chinese SMEs. *Intertrade, 11*, 12–20. https://doi.org/10.14114/j.cnki.itrade.2019.11.003

UNIDO. (2021). *Industrial Development Report 2022*. *The Future of Industrialization in a Post-Pandemic World*. UNIDO. https://www.unido.org/sites/default/files/files/2021-11/IDR%202022%20OVERVIEW%20-%20EN%20EBOOK.pdf

Wang, Z., Wei, S. J., & Zhu, K. (2013). Quantifying international production sharing at the bilateral and sector levels (No. w19677). National Bureau of Economic Research. https://www.nber.org/system/files/working_papers/w19677/w19677.pdf

Wu, Y., & Ma, Y. (2020). The Impact of Manufacturing Input Service on Value Chain Upgrading: Dual Perspectives based on Participation and Division of Labor. *Commercial Research*, *2*, 62–72. https://doi.org/10.13902/j.cnki.syyj.2020.02.007

Xu, J., & Xia, J. (2020). The Development of Digital Trade from the Perspective of Global Value Chain: Strategic Positioning and China's Path. *Reform, 5*, 58–67.

Yu, N. (2021). The Shaping and Transformation of the "Axial Age" of the Global Digital Economic Value Chain. *Journal of East China Normal University (Humanities and Social Sciences), 4*, 124–135. https://doi.org/10.16382/j.cnki.1000-5579.2021.04.012

Yang, L. (2015). Imported Producer Services Affects Manufacturing Servitization. *The Journal of Quantitative & Technical Economics, 5*, 37–53. https://doi.org/10.13653/j.cnki.jqte.2015.05.003

Zhang, Q., & Yu, J. (2020). Input Digitization and Climbing Global Value Chain: Micro Evidence from Chinese Manufacturing Enterprises. *Economic Review, 6*, 72–89. https://doi.org/10.19361/j.er.2020.06.07

Zhang, Q. & Yu, J. (2021). Input Digitization of Manufacturing Industry and Upgrading in GVC: Reexamination based on the Difference of Input Source. *Journal of Finance and Economics*, *9*, 93–107. https://doi.org/10.16538/j.cnki.jfe.20210616.203

Zhang, Y., Ling, D., & Liu, H. (2022). Does the digital economy promote the upgrading of global value chain in China's manufacturing?. *Studies in Science of Science*, *1*, 57–68. https://doi.org/10.16192/j.cnki.1003-2053.20210326.003