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How Does GVCS Participation Influence Manufacturing Productivity? The Case of China

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ABSTRACT: The theoretical and empirical studies argue ambiguous effects of GVCs participation of developing countries on productivity. By using panel data of 15 Chinese manufacturing industries over the 2005-2014 period, we find that China's GVCs backward and forward linkages contributed to labor productivity growth of 6.41% and 1.97% per year on average respectively, via drawing out from low value added low labor cost backward linkages sectors, optimizing resource allocation towards more efficiency manufacturing sectors (rarely studied) and developing higher value added forward linkages. The resulting structural transformation along to the rise of labor costs diminished the risk for Chinese manufacturing industry to be trapped in low-profitability low productivity GVCs activities. However, the productivity contribution of moving out from backward linkages 3 times higher than that of forward linkages suggest that the future positive impact of GVCs on productivity may be much more difficult to realize in particular in a less favorable context (trade war between China and USA, reindustrialization of developed countries and trade protection related to Covid-19 etc.) than the studied period.

KEYWORDS: global value chains, manufacturing labor productivity, China

1. INTRODUCTION

The participation of developing countries into global value chains (GVCs) may impact their productivity through importing and exporting intermediate goods (Criscuolo and Timmis, 2017). By importing qualified foreign intermediate goods and interacting with multinationals, developing countries adopt foreign technologies and management to match international standards and benefit from learning externalities and technology spillovers (Kowalski et al., 2015; Pahl & Timmer, 2019). They are motivated to invest in new processes, technologies and skills to survive from the higher competition from imports (Tajoli and Felice, 2018; Shu and Steinwender 2019). By access to larger export markets and the engagement in higher quality export activities of intermediate goods, developing countries are incentivized to improve the production efficiency and the quality of their products and to diversify and upgrade towards new and higher value added activities (Bustos, 2011; Li and Liu, 2014; Ndubuisi and Owusu, 2021). The higher competitive pressure from GVCs participation optimizes resources reallocation to more productive firms, while the least productive ones are forced to exit the market (Leibenstein, 1966; Melitz, 2003; Melitz and Ottaviano 2008; Eslava et al. 2013; Guillaumont Jeanneney and Hua, 2001).

These potential positive GVCs effects on productivity depend on the position of developing countries inside global value chains in function of their comparative advantages (Banga, 2014; Ignatenko et al., 2019) and their capacity to assimilate technology transfers. They may be mitigated or even reversed if developing countries are unable to seize opportunity provided by GVCs to upgrade up towards new and higher value added activities along to the rise of labor costs in such way that the countries may be stuck in 'middle income trap' (Dalle et al., 2013 and UNCTAD, 2013), or prematurely deindustrialized (Rodrik, 2016, 2018). The productivity impact of GVCs participation is thus theoretically ambiguous for developing counties, needs an empirical investigation.

[1] This research was presented at the XVIII Workshop on Economic Integration, INTECO University of Valencia 25th and 26th of November 2021, and the similar in Economix February 11, 2022. It benefited from conference discussions for valuable comments. All the remaining errors are mine.

The empirical literature on the productivity impact of GVCs is emerging. It often uses backward linkages index measured as share of foreign value added in exports, and/or forward linkages index calculated as share of domestically produced intermediate inputs embodied in third countries' exports proposed by Koopman et al. (2014) etc. to estimate GVCs impacts on productivity. By using multi-countries multi-sectors data over different periods including developed and developing countries, the literature finds either positive productivity effects of backward linkages, forward linkages or both of them (Baldwin and Yan, 2014; Kordalska et al., 2016; Kummritz, 2016; Constantinescu et al., 2019 and Urata and Baek, 2020 etc.), or negative ones of backward linkages (Yanikkaya and Altun, 2019). Few studies have been made at a country multi sectors level except for Banh et al. (2020), who find a negative impact of downstream industries' GVCs participation on productivity in Estonia. The empirical results show that the impact of GVCs on productivity is uncertain, depending on studied countries and periods.

To contribute this emerging literature, the objective of this study is to analyze the impact of China's GVCs participation on manufacturing productivity. China actively participates in GVCs, initially via labor intensive processing and assembly activities profiting one of the lowest labor costs in the world in 1980s and 1990s, becomes one of the main manufacturing GVCs centers in the world[†]. Along to the rise of labor costs, China makes great efforts via "made in China in 2025" program particularly since its adhesion into WTO in 2001 to push industry diversifying and moving up. The Chinese industrialization experience provides an excellent example to study the productivity impacts of its GVCs backward and forward participation to compare to previous studies.

Fig. 1 shows that while the share of China's foreign value added in exports relative to its gross exports, i.e. China level backward linkages, decreased of 3.36% per year on average over the 2005-2014 period for 15 manufacturing industries, its labor productivity improved at an annual average growth rate of 13%. It shows that the relationship between sector level backward linkage (i.e. share of sector's foreign valued added in sector's exports) and its related productivity is negative once time and section fixed effects are controlled, while the correlation between the share of sector's foreign valued added relative to China's gross exports, named as structure level backward linkage, and sector productivity is positive.

One possible explanation is that China has lost comparative advantage in low cost labor intensity processing and assembly situated in the end of GVCs during the studied period of 2005-2014 because of the strong rising labor cost. The annual average growth rate of real salaries in manufacturing increased at 14% on average per year, passed from 2247 $/employee in 2005 to 6977 $/employee in 2014. The rising labor cost reduces profit margin and exerts two opposite effects. On the one hand, it reduces the imports of intermediate goods destined to be processed and assembled by pushing multinationals leaving China to other low labor cost countries, and by obligating Chinese exporters to buy locally produced varied but less expensive intermediate goods to produce their final exports to survive. This import besides ordinary trade regime, Chinese customs authorities established a processing trade regime in 1979 under which foreign inputs are imported duty-free for further processing, assembly and reexporting.

substitution by domestic ones becomes possible thanks to the expansion of local firms able to produce varied less expensive intermediate goods after a longue period of learning by doing from multinationals since China's open door policies in 1979 (Kee and Tang, 2016; Duan et al. 2018; Chor et al., 2021). Consequently, the share of processed and assembly in total exports decreased from 55% in 2005 to 36% in 2015, and from 28.2% to 18.7% for the share of foreign value added in gross exports.

On the other hand, the high labor cost pushes Chinese manufacturing firms making great effort by eliminating excess labor or by introducing labor saving techniques (automatization of production chains etc.) to increase efficiency in production. This may increase the productivity of surviving manufacturing firms as some of them are obligated to close the less performing factories or even disappear; it is a kind of Schumpeterian "creative destruction" benefiting to the most performing enterprises (Guillaumont Jeanneney and Hua, 2001).

On contrary, it is also probable that imports of intermediate goods favor productivity. The high labor cost incites Chinese dynamic firms particularly in high tech sector to import core technologies they are unable to produce domestically from international suppliers to develop directly their own higher value added brands able to compete in domestic and world market, thus increase strongly productivity (ADB, 2021). This one step development strategy from importing core technologies to develop domestic own brands is facilitated by GVCs in which the complex intermediate goods of core high technologies are divided into many small international standardized parts and components which are built in different countries all over the world according to their comparative advantages and are incorporated into Chinese local branded products to be exported to consumers all over the world. This manufacturing modularization allows for example Chinese mobile phones firms (Huawei, OPPO and Xiaomi etc.) concentrating on developing less sophisticated noncore technology activities and creating their own brands (ADB, 2021). Consequently, the net impact of share of foreign value added in exports on productivity is uncertain, needs an empirical investigation.

Moreover, the strong development in high technology sector in China allows optimizing resource reallocation of production factors inside manufacturing sectors towards more productive ones, leading the rise of the Chinese manufacturing productivity on average. It is the case of computer, electronic and optical products sector which becomes the biggest one with highest productivity relative to other sectors in China. This positive effect of resource reallocation towards more efficiency industries can be captured by the relationship between sector's share of foreign value added in exports relative to China's gross exports, which measures magnitude of each sector relative to others and productivity (OECD, 2018). This effect is rarely studied in GVCs literature.

Finally, the productivity effect of manufacturing industry passes through GVCs forward linkages and position. The share of Chinese intermediate goods embodied in exports of third countries relative to gross exports increased 0.97% on average per year over the period. The moving up from drawing out from backward linkages into forward linkages improved Chinese GVC position from 0.3 in 2005 to 0.8 in 2015. We suppose that the effects of forward linkage and position are positive. To measure the global effects, we estimate the effect of GVC participation index which is the sum of backward and forward linkages on productivity. Its impact is uncertain, depending which linkage exerts higher impact.

To verify the above arguments, we estimate the impacts of Chinese GVC participation on productivity by using panel data of 15 manufacturing industries over the 2005-2014 period from OECD TiVA and WIOD databases[2]. In order to compare to previous studies, we begin to estimate a simple reduced-form model to investigate the impact of GVC backward and forward linkages on productivity by controlling time and sector fixed effects as Kummritz (2016) and Urata and Baek (2020), and we extend this investigation to GVC participation and position indices and resource reallocation effects. We obtain a negative coefficient of sector level GVC backward linkages conform to the observed statistical relationship and to the results obtained in Yanikkaya and Altun (2019) and Banh et al. (2020) and a positive coefficient of structure backward linkages, confirming the positive resource allocation effects in favor of more productive sectors. We find that GVC forward linkage and position indices exert positive impacts on productivity, while the effect of GVC participation is statistically insignificant probably due to the opposite effects of backward and forward linkages[3].

We make several robustness tests to verify the stability of the above baseline results. A major obstacle in empirical macroeconomic literature on trade and growth is the bias due to omitted variables. The bias in the baseline estimations is here mitigated because time and sector fixed effects allow capturing common factors for GVC participation indices and productivity. We still check if other potential omitted variables such as capital intensity, trade variables and real exchange rate bias the baseline results. It is well known that China's labor productivity was boosted by a rapid growth of investment and then of capital intensity (Guillaumont Jeanneney and Hua, 2001). We followed Kordalska et al. (2016), Constantinescu et al. (2017), Yu and Lou (2018), Gal and Witheridge (2019) and Montalbano and Nenci (2020) among others to estimate a GVC augmented production function which allows us to add capital intensity into the baseline function. We then follow Constantinescu et al. (2019) to add non GVC related trade variables which may exert productivity effects through enhanced competition via imports and exports (Amiti and Konings 2007; Goldberg et al. 2010, De Loecker 2013). Moreover, Guillaumont Jeanneney and Hua (2001) evidenced the impact of real exchange rate on labor productivity in the case of China over the 1986-2007 period via several transmission channels. We added real exchange rate into the baseline equation to control the effects.

A second issue arising from estimating the above models is potential endogeneity bias. It is possible that an industry with high productivity growth is easier than others to be engaged in GVCs (Del Prete et al., 2017; Urata and Baek, 2021). To control the reverse causal relationship, we followed Banh et al. (2021) to use the average world level GVCs indices as instrumental variables (IV) to estimate the effects of China's GVCs participation modes on its labor productivity. The instrumentation supposes that the driving forces of GVC participation are the same for China and for the world. The validity of instruments variables is confirmed by econometric tests. The results of the robustness tests do not modify the baseline results.

The obtained results in this study show that the positive productivity effect of China's GVCs participation resulted from optimizing resource allocation inside backward linkages activities towards more efficient ones, from moving out from low productivity sectors of processing and assembly exports to higher productivity sectors of intermediate goods supplying to Chinese exporters or to be embodied in exports of third countries and from the GVC position improvement, which lead a structural transformation in manufacturing industry.

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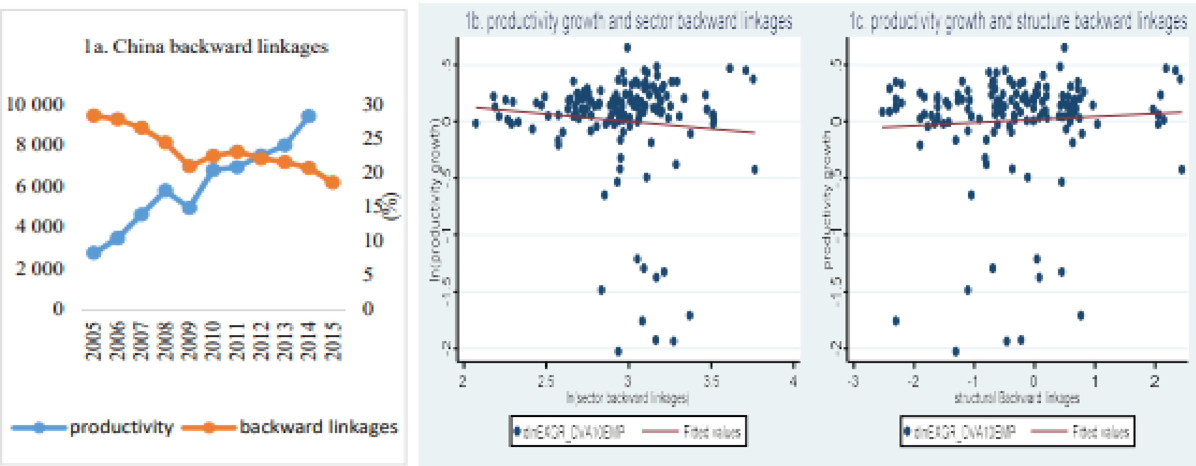
[2] We have excluded the petroleum sector because of its special characters. Moreover this sector is under the state control in China. The estimation period ends in 2014 because of data availability.

[3] See table 1 in section 4 for the econometric results.

This study contributes to the literature in several ways. Few studies have been made at a country multi sectors level whose advantage is to avoid heterogeneities across countries, in particular for a large country as China. This study completes this gap by estimating the impact of GVCs on sectoral manufacturing productivity in China. The second originality is to investigate the effects of GVC participation and position besides backward and forward linkages, while the literature focused the last two ones. The obtained results support the arguments of Banga (2014) and Ignatenko et al. (2019) that participating into GVCs is not enough to take gains. It depends on countries' capacity of moving up their position across value added chains (Costinot et al., 2013; Criscuolo and Timmis, 2017). The third originality is that this study evidenced positive effects of resource reallocation towards the most efficient sectors on productivity improvement, while the literature ignored this effect. This study extended the literature on the effects of China's GVC participation, which focused on domestic value added in exports (Koopman et al., 2014, Kee and Tang, 2016; Meng et al., 2017; Yu and Luo, 2018; Taguchi and Li; 2018; Hua, 2022 etc.), or productivity at firm level (Lu et al., 2016; Ge et al. 2018; Chor et al., 2021). It finally contributed the literature on the determinants of labor productivity in China. A plethora of literature has explained the rapid growth of labour productivity in China, but the role of GVC has not yet been considered (Guillaumont Jeanneney and Hua, 2011).

The rest of this paper is organized as following. Section 2 presents analysis methods, which are applied to panel data for 15 Chinese manufacturing industries over the 2005-2014 period in section 3 in which the obtained results are presented and discussed. The political and economic implications are given in the conclusion.

Fig. 1. Relationship between labor productivity and GVCs backward linkages of Chinese manufacturing industry over 2005-2014 period



Notes: Labor productivity is calculated as nominal domestic value added of 15 manufacturing industries deflated by price of gross value added (2010=100) and divided by numbers of employees. China/sector backward linkage is measured as the share of foreign value added embodied in China's/sector's domestic exports relative to China's/sector's gross exports. Structure backward linkage is calculated as the share of sector level foreign value relative to China gross exports. Industry and year fixed effects are controlled in Fig. 1b and 1c.

Source: OECD TiVA and WIOD databases.

2. METHODS

To estimate the impact of sector level GVCs participation relative to its exports on productivity, we follow the studies of Kummritz (2016) and Urata and Baek (2020) to use a simple reduced-form model such as:

$$\ln LP_{it} = a_0 + a_1 lnGVC_{iit} + \mu_i + \pi_t + \varepsilon_{it} \qquad (1)$$

Where LP_i is sector labor productivity, GVC_{ii} represents respectively sector level backward, forward, participation and position indices relative to sector's exports. i represents manufacturing sectors, t years. μ_i captures sector fixed effects, π_t captures year-fixed effects, ε_{it} is error terms. Year and sector fixed effects are included to control for common macro shocks at the sector levels that may also affect productivity. All variables are taken in natural logarithm so that the coefficient a_1 is interpreted as elasticities. Its sign is waited to be negative for sector level backward linkages as suggested in Fig. 1b, but positive for structure backward linkages as shown in Fig. 1c. It is also waited positive for forward linkage and position indices, but ambiguous for participation index.

Lu et al. (2016) found an inverted U-shaped non-linear relationship between GVC backward participation of Chinese firms and their TFP for 2000 to 2006 period. To test possible nonlinear effects of GVCs backward linkages on productivity, we add backward linkage in square form to equation 1 as following:

$$\ln LP_{it} = a_0 + a_1 lnFVA\_SH_{iit} + a_2 lnFVA\_SH_{iit}^2 + \mu_i + \pi_t + \varepsilon_{it} \quad (2)$$

Where FVA_SH_{iit} and $FVA\_SH_{iit}^2$ represent respectively sector backward linkages and its square form. A statistically significant and negative sign of coefficient a_2 confirms an inverted U-shaped non-linear relationship and suggests that the effect of GVCs backward linkages on productivity is positive in first period and is reversed in the second period. In this case we can calculate a turning point to check the positions of 15 Chinese manufacturing industries during the studied period.

To estimate the effects of structure level GVC participation indices, we replace GVC_{ii} in equation 1 by structure GVCs linkages as following ln

$$\ln LP_{it} = b_0 + b_1 lnGVC_{ict} + \mu_i + \pi_t + \varepsilon_{it} \quad (3)$$

Where GVC_{ic} respectively represents structure level GVC backward, forward, participation and position indices. The coefficient of b_1 is waited to be positive.

We make several robustness tests to verify the stability of the baseline equations. Firstly, variable omissions may bias the results of baseline equations. Production factors may influence productivity as suggested Cobb-Douglas production function. We follow Kordalska et al., (2016), Constantinescu et al. (2019), Yu and Lou (2018), Gal and Witheridge (2019), and Montalbano and Nenci (2020) among others to write a production function as following:

$$DVA = AK^{\alpha} L^{(1-\alpha)}$$

Where DVA represents real domestic manufacturing value added in exports, A technology shifter which is supposed to be captured by GVC participation, K real capital stock and L employment in manufacturing sector. Dividing the above equation by L and taking natural logarithms, and adding sector- and year- fixed effects and an error terms yields the following reduced form:

$$lnLP_{it} = a_0 + a_1 lnGVC_{it} + a_2 ln(\frac{K}{L})_{it} + \mu_i + \pi_t + \varepsilon_{it} \quad (4)$$

The equation 4 allows us to test if the omission of capital intensity variable biased the baseline results obtained in baseline equation 1.

The underlining hypothesis of the baseline equations is that only GVC related trade are considered as potential technology shifters, i.e. as determinants of the technological change term (Kordalska et al., 2016). However, it is well known that non-GVC related trade exerts impact on productivity (Constantinescu, et al., 2019). Their omission may also bias the results. We thus added two non-GVC related trade variables into the equation 4 such as

$$lnLP_{it} = a_0 + a_1 lnGVC_{it} + a_2 ln(\frac{K}{L})_{it} + a_3 lnX_{it} + a_4 lnM_{it} + \mu_i + \pi_t + \varepsilon_{it} \quad (5)$$

Where X represents non-GVC related exports, M non-GVC related imports.

Moreover, Guillaumont Jeanneney and Hua (2001) evidenced that real exchange rate influenced labor productivity through many channels in the case of China over the 1986-2007 period. We added real exchange rate to capture international competitiveness.

$$lnLP_{it} = a_0 + a_1 lnGVC_{it} + a_2 ln(\frac{K}{L})_{it} + a_3 lnRER_{it} + \mu_i + \pi_t + \varepsilon_{it} \quad (6)$$

3. RESULTS AND DISCUSSION

The above equations from 1 to 6 are estimated for 15 Chinese manufacturing industries over the period from 2005 to 2014 using OECD TiVA and WIOD databases (see table A1 for the list of sectors). The analysis period and the sample size are determined by data availability on the OECD Trade in Value Added (TiVA) and World Input-Output Database (WIOD) databases. The OECD TiVA publishes data over the period from 2005 to 2015 for 16 manufacturing sectors. The WIOD published Socio Economic Accounts Release 2016 available February 2018 over the period from 2000 to 2014 for 18 manufacturing sector (Timmer et al., 2015). Both databases use an industry list based on the International Standard

Industrial Classification (ISIC) Revision 4 and used 2008 System of National Accounts (SNA) concepts allowing for data compatibility. The sectors 17 (manufacture of paper and paper products) and 18 (printing and reproduction of recorded media) in WIOD are regrouped into a sector (paper products and printing) as in TiVA, as well as the sectors 20 (Manufacture of chemicals and chemical products) and 21 (Manufacture of basic pharmaceutical products and pharmaceutical preparations) into a sector (Chemicals and pharmaceutical products). The Socio-economic accounts of WIOD contain sector level data on employment, capital stocks, gross output and value added at current and constant prices. Data for the sector "Coke, refined petroleum and nuclear fuel" are excluded to minimize distortions from specific dynamics of fuel and petrochemical exports. The definitions and the sources of data are the following and resumed in table A2.

Labor productivity is calculated as the ratio of domestic value-added obtained from OECD TiVA database deflated by the Chinese value-added price (2010=100) from World Input-Output Database and divided by numbers of employees reported in WIOD database. Fig 2 shows the evolution of labor productivity over the 2005-2014 period. The labor productivity in computer & electronics sector increased from 4621 $/person in 2005 to 26 301 $/person in 2014 at an annual average growth rate of 19.1%, and gained 4 places to become the highest labor productivity sector in 2014. The paper & printing sector had the smallest productivity during the studied period which increased from 379 $/person in 2005 to 2185 $/person in 2014. The labor productivity in other manufacturing sector as the second largest sector increased from 4630 $/person in 2005 to 19481 $/person in 2015 at an annual average rate of 16.1%. It is followed by basic metals sector, other transport equipment sector, electrical equipment, machine and equipment and chemical sectors. The labor productivity in textile & apparel sector passed from 2660 $/person in 2005 to 8457 $/person in 2014, i.e. at an annual growth rate of 12.5% on average.

Sector level GVC backward linkage is measured as the share of imported intermediate goods embodied in a domestic sector from foreign sector upstream in global production chain, and captures the intensity of foreign value added or import content in a sector's exports. A high share indicates that the sector mainly engages in final assembly of imported inputs from other countries and thus strongly depends on the rest of the world. A decreasing value signifies that sector moves up from final stage of global value chains to higher productivity sector.

Fig 2. Evolution of labor productivity in 15 manufacturing sectors in 2005 and 2014

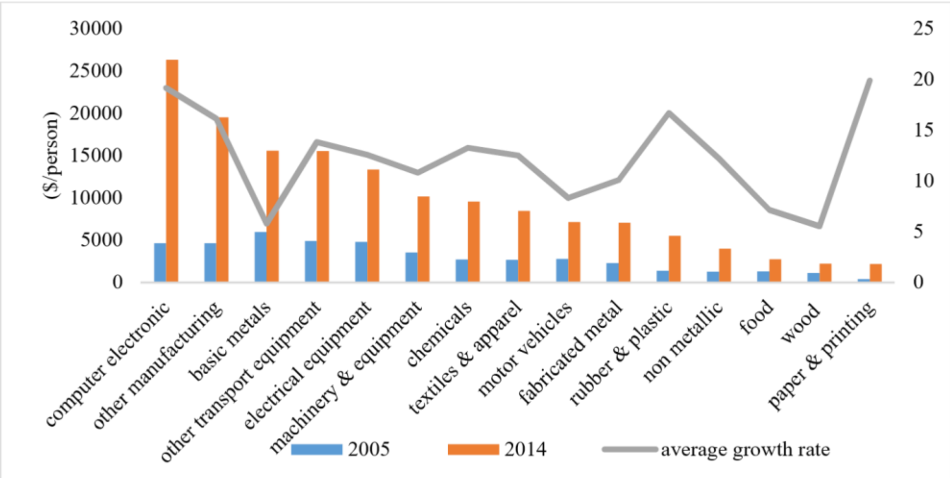


Fig 3a shows the evolution of sector backward linkages for 15 Chinese manufacturing sectors in 2014 relative to 2005. It decreased for all sectors. As waited, the ICT & electronics sector has the highest share of foreign value added relative to its exports, which decreased from 43% in 2005 to 32% in 2014, i.e. a decrease of 11 percentage points during the period. The share decreased 8 percentage points for four sectors (electrical equipment, other transport, rubber & plastics, paper & printing), followed by the machinery sector. The textiles and apparel sector's share decreased from 17% in 2005 to 11% in 2014.

Structure level GVC backward linkage is measured as the share of imported intermediate goods embodied in sector from foreign industry upstream in global production chain relative to China's exports, and thus measures the magnitude of a sector relative to other sectors (OECD, 2018). A high share indicates the concentration of foreign value added in a sector relative to others. In China, the ICT & electronics sector is the most important sector participating GVCs backward linkage activities relative to other ones with its share of foreign value added in exports relative to China's exports decreased from 11.5% in 2005 and decreased to 7% in 2014 (Fig 3b). The textile and apparel sector was the second sector with its share decreased from 3% in 2005 to 1.7% in 2014. Its 2nd place in 2014 was replaced by electronical equipment sector whose share decreased from 2.1% in 2005 to 1.9% in 2014.

Sector/structure forward linkage is calculated as share of domestic value added embodied in intermediate exports of sector that are further re-exported to third countries relative to sector/China gross exports. Sector forward linkage measures exports of intermediate goods that are used as inputs for the production of exports of other countries. An increasing share suggests that the sector is moving up in the GVCs to start producing intermediate goods for other countries, especially when more and more of these goods are exported to third countries for final goods production. It reflects the dependence of the rest of the world on the country. Structure forward linkage measures the magnitude of a sector relative to the rest in producing intermediate goods.

Fig 3c shows that the evolution of sector forward linkages in 2014 relative to 2005, which increased for all sectors except for four (wood, food products, other transport and motor vehicles). The highest share of intermediate goods exported to third country is basic metals industry, which increased slightly from 73% in 2005 to 74% in 2014, while other manufacturing has the lowest share from 15% in 2005 to 16% in 2014. The forward linkages of ICT & electronics sector increased the quickest, passed from 27% in 2005 to 32% in 2014, while it decreased for the motor vehicles from 32% in 2005 to 26% in 2014. The share increased from 33% in 2005 to 35% in 2014 for textile & apparel sector. Fig 3d shows that ICT & electronics sector has the most important share in structure forward linkages which decreased from 4.4% in 2005 to 3.4% in 2014, following by motor vehicles whose share increased from 1.5% to 1.9%.

Sector/structure GVC participation is the sum of sector/structure forward and backward linkages. Sector GVC participation measures the extent to which a sector is involved in the global production chain. It decreased in all sectors in 2014 relative to 2005. The motor vehicles and other transport and ICT & electronic sectors lost respectively 8.5%, 7.7% and 6.7%
(Fig. 3e). The structure GVC participation decreased from 16% in 2005 to 11% in 2014 for ICT & electronic sectors, from 4% to 3 % for textile and clothing.

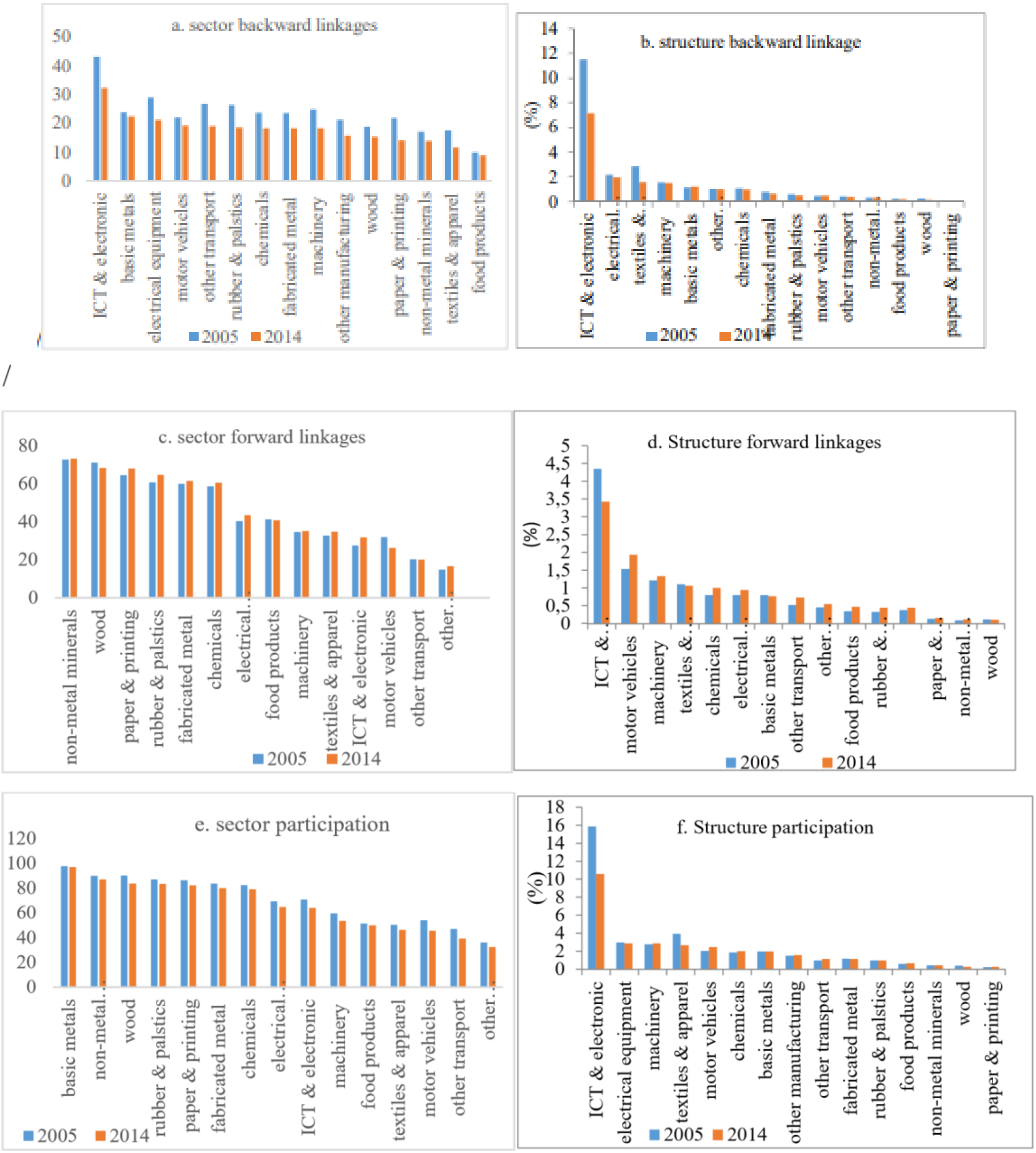
Sector/structure GVC position is measured as the log ratio of a sector's supply of intermediates used in other countries' exports to the use of imported intermediates in its own production either relative to sector/China exports. Sector GVC position characterizes the relative position of a sector to gauges whether a sector is likely to be in the upstream or downstream of the global value chain (Koopman et al., 2014). A positive index means that sectors are relatively upstream by producing inputs for others, thus contributing more value added to other countries' exports than other countries produce, and contribute to theirs. A negative one suggests that sectors are relatively downstream by importing a large portion of intermediates from other countries to produce its final goods. Structure position captures the magnitude in a sector relative to the rest.

All GVC position indices are positive except for other transport, other manufacturing and ICT & electronic sectors in 2005. Their positions improved for all sectors in 2014 relative to 2005 except for motor vehicles sector. The positions of other transport and other manufacturing became positive, while that of ICT & electronics sector was still negative in 2014, meaning that this sector imported more intermediate goods to produce final goods. Even still lightly negative, ICT & electronics sector improved its position among the best just after paper & printing, textiles & apparel sectors. Relative to China's gross exports, only four sectors (motor vehicles, other transport, foods and paper & printing sectors) have positive position indices, while ICT & electronic and electronic sectors have the highest negative position indices.

Capital intensity is the ratio of nominal capital stocks deflated by the price of intermediate goods and divided by number of employees. Capital stocks and number of employees of manufacturing sectors comes from WIOD database. The capital intensity of all manufacturing sectors increased quickly in 2014 relative to 2005. Only two sectors increased at annual average growth rates less than 10% (8.3% and 9.5% respectively for the coke & petroleum sector and for food sector). Others increased from 11% per year at average for chemicals to 17% for fabricated metal sector (17.6%). The capital intensity increased 17% per year at average for ICT & electronic sectors and 15% for textiles & apparel sector and 17.3% for other manufacturing sector. Real exports of final products are calculated as nominal exports of final products deflated by industrial price. Real imports of final products are calculated as nominal imports of final products deflated by industrial prices. Real exchange rates are calculated as nominal exchange rate multiplied by the report of sector value added price in US and in China.

Before making econometric regressions, we need to know if the variables are stationary at an absolute level to avoid spurious results. We apply Levin-Lin-Chu panel data unit-root tests in which time trend and panel-specific means (fixed effects) options are used; the variables are lagged by one period. We subtract the mean of the series across panels from the series to mitigate the impact of cross-sectional dependence (Levin et al. 2002). The results, reported in Table A2, allow us to reject the null hypothesis that panels contain unit roots, so we can accept the hypothesis that the variables are stationary at an absolute level. We then apply Hausman specification test and its results show that fixed effect estimations are preferred to random effect ones (Table 1).

Figure 3. Evolution of GCVs participation indices for 15 Chinese m



A potential econometric problem is the endogeneity of explanatory variables. This is a difficulty met in all the estimations on macroeconomic data, due to the possibility of a reverse causal relationship, i.e. an industry with high productivity growth is more likely to be engaged in GVCs, due to measurement error, i.e. GVC indicators are estimated using Leontief decomposition and to the risk of omitted variables. We used an instrumental variable (IV) approach to estimate the effects of GVC participation on labor productivity. We follow Banh et al. (2020) to use world average industrial GVC indices to instrument China's GVC participation for the same industries, which are strongly correlated. This suggests that the driving forces of China's GVC participation of a particular sector are similar to those at the world level on average. The obtained results of Davidson-MacKinnon exogeneity test reject the null hypothesis of exogeneity in favor of endogeneity. The pertinence of the instruments for the IV estimation is confirmed by the results of under identification test based on Kleibergen-Paap rk LM statistic and the weak identification test based on the Kleibergen-Paap Wald rk F statistic which exceed the Stock and Yogo (2005) critical values in all cases (table 1).

The above equations are estimated using OLS and IV methods. From Table 1 we can see that the results of OLS and IV estimations with sector and year fixed effects are similar. We prefer the IV estimation results according to the results of endogeneity tests. The following comments are made with the results of IV estimations. The coefficient of sector backward linkages is negative and statistically significant (-2.36, column 1.6 part 1 Table 1). As the share of foreign value added relative to exports at sector level decreased over the 2005-2014 period, Chinese sector GVC backward linkage contributed productivity improvement by moving out from processing and assembly exports. The annual average contribution of sector GVC backward linkages to productivity can be calculated as the product of the coefficient of sector GVC backward links multiplied by the annual average rate of foreign value added share (-3.36%), which is equal to 7.93% ((-2.36)*(-3.36%)) (column 3, Table 2). The coefficient of sector backward linkage in square is negative and statistically significant (-0.97) (column 1.7, Table 1). As the shares of foreign value added relative to exports are superior to the turning point estimated to 6.90 at sector level, all manufacturing sectors are positioned on the decreasing trend. These results suggest that Chinese manufacturing firms are not yet competitive in low labor cost low value added processing and assembly exports and their leaving from these activities strongly contributes to improve productivity.

As waited, the coefficient of structure backward linkages is positive and statistically significant (0.48, column 2.5, part 2, Table 1), suggesting that resource reallocation towards more efficiency sector increases productivity on average. The decrease of structure backward linkages of 3.17% per year on average contributed to diminish -1.52% (-3.17%*0.48) of productivity per year on average (Table 2). In total, the GVCs backward linkages contributed to increase productivity of 6.41% per year on average (column 3, Table 2).

The results show a positive coefficient for sector GVC forward linkages, which is estimated to 2.14 (Column 1.8, part 1, Table 1). As the share of domestic value added embodied in intermediate exports relative to gross exports named GVC forward links increased at annual average growth rate of 0.95%, sector GVC forward links improved labor productivity at an annual growth rate of 2.03% (2.14* 0.95%) on average (column 3, table 2).

The coefficient of structure forward linkages is estimated to 0.57 (column 2.6, part 2, Table 1). The annual average decrease of structure forward linkages of 0.10% diminished productivity of -0.06% per year on average. In total, structural forward linkages contributed the productivity improvement of 1.97 % on average per year (Table 2).

While the coefficient of sector GVC participation (i.e. the sum of sector GVC backward and sector forward links) is not statistically significant (Column 1.9, Table 1), that of structure participation index is statistically significant with estimated coefficient of 0.39. GVC position (i.e. log difference between forward linkages and backward linkages) is statistically significant with estimated coefficient of 2.06 at sector level (Column 1.8, Table 1) and 1.20 at structure level respectively.

We check the stability of the above baseline results. The obtained results of robustness tests show that capital intensity does not play a statistically significant role and its adding into equation 1 does not change the obtained coefficients of GVCs (columns 2.1 to 2.10, table 3). When real exports and imports of final products are added into equation 2, we find that only the coefficient of exports is statistically significant (columns 3.1 to 3.10, table 3). It suggests that non GVC related exports exert positive effect on productivity. When real exchange rate is added, we find that real exchange rate exerted a significant effect in all equations (columns 4.1 to 4.10, Table 3). Any ways, the addition of capital intensity, GVCs non related trade variables and real exchange rate do not modify the results of baseline equations.

From the above results we can see that China's GVCs participation exerted positive productivity effects mainly via moving out from low value added backward linkages, but also via optimizing resource allocation inside sectors towards more efficiency ones, via the development of higher productivity forward linkages and via improving its position. This structural transformation towards more efficient higher value added sectors along with the rise of labor cost is essential to keep high productivity to compensate the high increase in labor costs and to reduce the risk of being stuck in low-value-added tasks and to industrialize.

We observe that the contribution of GVCs linkages to labor productivity improvement mainly passed through moving out low labor cost sectors, and it is three times higher than that of higher value added forward linkages. This suggests that the future productivity improvement may be more difficult, because the moving up towards intermediate goods with sophisticated technological content is more complicated, while China has lost comparative advantages in low cost labor intensive backward linkages. We observe that, despite the sensible improvement, the GVC position of ITC and electronic sector is still negative and situated in the end of global value chains, depending thus more foreign countries than the last ones depend on China. We observe that the contributions of structure level GVC backward and forward linkages are negative, suggesting the difficulties to reallocate resources to efficient sectors. We observe that the massive physic capital-led productivity growth model does not play a significant impact on productivity growth. It suggests that the investment in R & D is essential in the future.

Table 1. Impact of GVCs on productivity of Chinese 15 manufacturing sectors 2005-14

	Part1: Sector level									
	OLS					2SLS				
	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
GVC sector backward linkages	-1.74*** (-4.69)	3.36*** (2.95)				-2.36*** (-5.32)	3.50** (2.11)			
GVC sector backward linkages²		-0.87*** (-4.57)					-0.97*** (-3.77)			
GVC sector forward linkages			2.12*** (3.66)					2.14*** (3.90)		
GVC sector participation				-0.61 (-0.50)					-1.69 (-1.32)	
GVC sector position					1.39*** (4.94)					2.06*** (6.07)
Hausman speciation test	24.78	29.3	30.47	27.2	19.84					
Davidson-MacKinnon test of exogeneity						15.49				
Underidentification test of Kleibergen-Paap rk LM statistic						23.1	25.1	13.8	13.9	14.0
Weak identification test of Kleibergen-Paap Wald F statistic						68.4	44.23	33.5	28.3	15.6
R^2	0.87	0.87	0.86	0.82	0.84	0.85	0.89	0.86	0.81	0.87

	Part 2: Structural level							
	OLS				2SLS			
	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8
GVC structure backward linkages	0.62** (2.56)				0.48*** (3.37)			
GVC structure forward linkages		0.74** (2.57)				0.57*** (3.27)		
GVC structure participation			0.64** (2.17)				0.39** (2.60)	
GVC structure position				1.41*** (5.47)				1.20*** (3.45)
Hausman test	30.47	31;7	26.8	19.32				

Davidson-MacKinnon test of exogeneity					12.34			
Underidentification test of Kleibergen-Paaprk LM statistic					80.46	85.47	98.32	34.56
Weak identification test of Kleibergen-Paap Wald F statistic					222.62	215.72	335	21.33
R^2	0.85	0.85	0.85	0.88	0.85	0.85	0.84	0.88

Notes. T-statistics are reported in brackets. *, ** and *** indicate significance at the 10%, 5% and 1% levels of confidence, respectively.

Table 2. Annual average contribution of GVCs backward and forward linkages to productivity growth

	Estimated coefficients	Annual average growth rates	Annual average contributions
	1	2	3=1*2
Sector backward linkages	-2.36	-3.36	7.93
Structure backward linkages	0.48	-3.17	-1.52
Total			6.41
Sector forward linkages	2.14	0.95	2.03
Structure forward linkages	0.57	-0.10	-0.06
Total			1.97

Source: Authors' calculation

Table 3. Impact of GVCs on labor productivity of 15 manufacturing sectors 2005-14, robustness tests

Capital intensity								
	2.1	2.3	2.4	2.5	2.6	2.8	2.9	2.10
Backward linkages	-1.74*** (-4.82)				-2.35*** (-527)			
Forward linkages		2.18*** (4.12)				1.98*** (3.95)		
GVC participation			-0.60 (-0.48)				-1.84 (-1.17)	
GVC position				1.40*** (5.60)				2.02*** (5.80)
Capital intensity	-0.05 (-0.44)	-0.19 (-0.91)	-0.08 (-0.27)	-0.13 (-1.05)	-0.05 (-0.34)	-0.18 (-1.32)	-0.07 (-0.44)	-0.15 (-1.00)
Hausman speciation test	30.47	30.86	23.82	22.45				

Davidson-MacKinnon test of exogeneity					15.19			
Underidentification test of Kleibergen-Paap rk LM statistic					25.8	14.8	14.1	14.1
Weak identification test of Kleibergen-Paap Wald F statistic					69.5	48.2	34.1	18.3
R^2	0.87	0.86	0.82	0.89	0.85	0.86	0.81	0.87
		Non GVCs r elated trade						
	3.1	3.3	3.4	3.5	3.6	3.8	3.9	3.10
Backward linkages	-1.21*** (-3.72)				- 1.73*** (-3.69)			
Forward linkages		1.78*** (4.11)				1.54*** (4.47)		
GVC participation			0.22 (0.30)				0.22 (0.25)	
GVC position				1.11*** (6.22)				1.30*** (5.45)
Capital intensity	0.14 (0.80)	0.04 (0.20)	0.14 (0.45)	0.08 (0.57)	0.14 (1.21)	0.06 (0.54)	0.19 (1.47)	0.07 (0.73)
Real exports of final products	0.80*** (5.02)	0.88*** (8.72)	1.03*** (6.74)	0.74*** (6.78)	0.71*** (6.59)	0.90*** (12.11)	1.01*** (9.42)	0.69*** (8.14)
Real imports of final products	0.07 (0.62)	0.04 (0.46)	-0.08 (-0.58)	0.12 (1.51)	0.13 (1.36)	0.02 (0.34)	-0.16 (-1.55)	0.16 (1.89)
Hausman speciation test	27.05	17.54	19.41	18.67				
Davidson-MacKinnon test of exogeneity					22.77			
Underidentification test of Kleibergen-Paap rk LM statistic					23.2	15.7	11.8	17.3
Weak identification test of Kleibergen-Paap Wald F statistic					61.7	45.5	16.4	16.4
R^2	0.93	0.94			0.91	0.94	0.92	0.94
		Real exch ange rate						
	4.1	4.3	4.4	4.5	4.6	4.8	4.9	4.10
Backward links	-1.43***				- 1.87***			
	(-3.97)				(-4.28)			
Forward linkage		1.87*** (3.58)				1.72*** (3.82)		
GVC participation			-0.30 (-0.34)				-1.21 (-0.89)	
GVC position				1.20*** (4.96)				1.89*** (5.69)
Capital intensity	0.12 (0.98)	0.03 (0.18)	0.18 (1.29)	0.04 (0.26)	0.10 (0.70)	0.05 (0.33)	0.18 (1.25)	-0.04 (-0.25)
Real exchange rate	0.58*** (2.30)	0.67*** (3.67)	0.82*** (0.37)	0.52*** (2.54)	0.50*** (3.21)	0.68*** (5.05)	0.81*** (5.63)	0.34** (2.24)
Hausman speciation test	20.49	26.85	11.50	21.34				

Davidson-MacKinnon test of exogeneity					11.94			
Underidentification test of Kleibergen-Paap rk LM statistic					26.7	14.5	13.3	13.7
Weak identification test of Kleibergen-Paap Wald F statistic					63.8	45.5	30.6	16.2
R^2	0.89	0.89			0.87	0.89	0.85	0.88
Sector-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observation	160	160	160	160	160	160	160	160
Number of sectors	16	16	16	16	16	16	16	16

Notes. T-statistics are reported in brackets. *, ** and *** indicate significance at the 10%, 5% and 1% levels of confidence, respectively.

4. CONCLUSION

The theoretical and empirical literature argues that the impact of GVCs participation on productivity is uncertain for developing countries, needs an empirical analysis. China provides an excellent case study due to its high implication into GVCs activities as one of main world GVCs centers and its capacity of moving up along to the rise of labor cost. By using panel data of 15 Chinese manufacturing industries over the 2005-2014 period from OECD TiVA and WIOD databases, we estimated the effects of four GVCs participation on manufacturing labor productivity. We find that while the productivity elasticity of the share of sector's foreign value added relative to its exports is negative, those of the share in sector's foreign value added relative to China's gross exports and sector/structure forward linkages are positive, as well as the improvement of GVCs position of Chinese manufacturing industry from 0.3 in 2005 to 0.7 in 2014.

China's GVCs participation exerted positive productivity effects mainly via moving out from low productivity backward linkages that are not yet competitive giving the high labor cost, but also via optimizing resource allocation inside sectors towards more efficiency ones, via the development of higher productivity forward linkages and via improving its position. This resulting structural transformation towards more efficient higher value added sectors has contributed to increase China's high productivity growth of 13% per year on average during the studied period compensating almost the rise of labor cost of 14% per year on average. This has reduced the risk of being stuck in low-value-added tasks for the Chinese manufacturing.

It seems however that the structural transformation toward high value added sector will be much more difficile to realize in the future because the moving up towards intermediate goods with sophisticated technological content is much more complicated, while China has lost its comparative advantages in low labor costs intensive backward linkages activities, its efficiency in capital intensive-led productivity growth model and in resource reallocation toward efficient sectors. The difficulty is furthermore accentuated by the actual unfavorable international context in which the trade wars between China and USA, and Covid-19 crisis have increased trade protection and the reindustrialization of developed countries). The emphasis on optimizing resource allocation towards efficient sectors and the development of research and development (R&D) in favor of high value added sectors will be essential to keep productivity growth to avoid to be stuck in the 'Middle Income Trap'.

This study is limited to the manufacturing sector. Future research may extend the analysis to more recent period if the data become available and to identify other channels through which China's GVCs participation impacts productivity, in particular the productivity effects of the participation of services industries in GVCs etc. It may extend the analysis to explore other economic and social effects such as on inequality, employment and environment.

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Table A1: 15 Manufacturing industry classification

Labels	Manufacturing sectors	TiVA_ Code	WIOD code	ISTC Rev. 4 codes
Food	Foods products, beverages & tobacco	D10T12	C10-C12	10-12
Textiles apparel &	Textiles, textile products, leather & footwear	D13T15	C13-C15	13-15
Wood	Wood and products of wood and cork	D16	C16	16
Paper printing &	Paper products and printing	D17T18	C17 C18	17, 18
Chemicals	Chemicals and chemical products	D20T21	C20 C21	20, 21
Rubber plastics &	Rubber and plastics products	D22	C22	22
Non-metal minerals	Other non-metallic mineral products	D23	C23	23
Basic metals	Basic metals	D24	C24	24
Fabricated metals	Fabricated metal products except machinery and equipment	D25	C25	25
ICT & electronics	Computer, electronic and optical products	D26	C26	26
Electrical equipment	Electrical machinery & apparatus n.e.c.	D27	C27	27
Machinery	Machinery and equipment n.e.c.	D28	C28	28
Motor vehicles	Motor vehicles, trailers & semitrailers	D29	C29	29
Other transport	Other transport equipment	D30	C30	30
Other manufacturing	Other manufacturing	D31T32	C31C32	31, 32

Table A2. Definitions, sources and unit root test of variables

Names of variables	Calculation methods	Sources	Levin-Lin-Chu unit-root test*
Labor productivity	Nominal domestic value added in exports deflated by valueadded price (2010=100) and divided by numbers of employees	OECD TiVA; World InputOutput Database	-7.8764
GVC backward linkage	share of foreign value added relative to gross exports	OECD TiVA	-6.6287

GVC forward linkage	Share of domestic value added embodied in intermediate inputs re-exported to third countries relative to gross exports	OECD TiVA	-7.6478
GVC participation	sum of forward and backward linkages	OECD TiVA	-5.8732
GVC position	log ratio of supply of intermediates used in other countries' exports to the use of imported intermediates in its own production	OECD TiVA	-7.0031
Capital intensity	ratio of nominal capital stocks deflated by the price of intermediate goods and divided by number of employees	WIOD	-5.6254
NON-GVC related exports	Nominal domestic value added in exports of final products deflated by the price of output (2010=100)	OECD TiVA	-5.5448
Non-GVC related imports	Nominal imports of final products deflated by the price of output (2010=100)	OECD TiVA	-4.9085
Real exchange rate	nominal exchange rate multiplied by ratio of sectoral producer price between US and China	International Financial Statistics, IMF, WIOD	-5.4007

Note: * Levin-Lin-Chu unit-root test (Ho: Panels contain unit roots) is made with time trend and panel-specific means (fixed effects) and subtracted cross sectional means options. The variables are lagged by one period. The results of adjusted t are reported in table corresponding p-value=0.0000 for all variables.