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# How did China's GVCs participation influence its manufacturing productivity?

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## *Abstract*

*By using panel data of 15 Chinese manufacturing industries over the 2005-2014 period from OECD TiVA and WIOD databases, the impact of China's GVCs participation on labor productivity is estimated. We find that while the productivity elasticity of the share of sector's foreign value added relative to sector's exports known as sector backward linkages is negative, that relative to China's gross exports named structure backward linkage is positive. As the annual average growth rates of both backward linkages are negative, China's backward linkages have contributed to productivity growth of 6.41% per year on average. We find that the positive productivity elasticity of the share of domestic intermediate goods embodied in exports of third countries relative to sector's exports, named sector forward linkages together with a positive annual average growth rate, and that relative to China's exports named structure forward linkages together with a negative annual average growth rate, have increased productivity of 1.97% per year on average. We find finally that GVCs position is improved from 0.3 in 2005 to 0.7 in 2014.*

*China's GVCs participation exerted positive productivity effects via optimizing resource allocation inside sectors towards more efficiency ones, via moving up from low productivity backward linkages to higher productivity forward linkages and via improving its position. This diminished the risk to be entrenched in low-profitability low productivity growth GVCs activities in China. However, the productivity contribution of backward linkages 3 times higher than that of forward linkage suggests that the future positive productivity impact of GVCs moving up may be much more difficult in a less favorable context (trade war between China and USA, reindustrialization and trade protection related to Covid-19 for example).*

JEL Classification Numbers: F62, F63, O5, O47

Keywords: global value chains, manufacturing productivity, China

## 1. Introduction

Global value chains (GVCs) participation of developing countries may improve their manufacturing productivity through facilitated access to higher quality, varied and sophisticated imported inputs and world export market, benefiting new ideas, technology transfer, management know-how and spillover from their interactions with multinationals, increased competition in domestic markets and specialization, etc. (Gereffi et al., 2005; Grossman and Rossi-Hansberg, 2008; Baldwin and Robert-Nicoud, 2014; Criscuolo and Timmis, 2017; Pahl & Timmer, 2019 etc.). These positive effects on productivity depend on position of developing countries in global value chains according to their comparative advantages (Banga, 2014; Ignatenko et al., 2019). They may be mitigated or even reversed if developing countries are unable to seize opportunity provided by GVCs to upgrade by moving up towards new and higher value added activities along to the rise of labor cost (Dalle et al.; 2013 and UNCTAD, 2013). The impact of GVCs on manufacturing productivity is thus theoretically ambiguous for developing countries, necessary an empirical investigation.

The recent emerging empirical literature estimated the impact of different modes of GVCs participation on productivity using multi countries-sectors data over different periods including developed and developing countries, and found either positive 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 effects of backward linkages (Yanikkaya and Altun, 2019)<sup>1</sup>. Few studies has been made at a country multi sectors level except for Banh et al. (2020), who found 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 studied periods.

To complete this literature, the objective of this study is to analyze the impact of China's GVCs participation on manufacturing productivity with an advantage to avoid the problem of heterogeneities across countries. China has actively participated in GVCs via processing and assembly activities and became one of the main centers in the world on the one hand and has made great efforts to push its industry moving up from low value added assembly exports

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<sup>1</sup> Koopman et al., (2014) proposed four indices to measure GVC participation activities: backward linkages measured as share of foreign value added in exports, forward linkages calculated as share of intermediate inputs embodied in third countries' exports, participation as sum of backward and forward linkages, and position as log difference between forward linkages and backward linkages.

towards higher value added ones particularly since its adhesion into WTO in 2001<sup>2</sup>. Chinese successful experience provides an excellent example to study the impact of GVCs backward and forward participation on productivity as in previous studies, and furthermore the effects of its position.

It is surprising to observe that while the shares of China's foreign value added in exports relative to its gross exports known as backward linkages decreased of 3.36% per year on average over the 2005-2014 period for 15 manufacturing industries, their labor productivity improved at an annual average growth rate of 13%<sup>3</sup>.

One possible explanation for this negative statistical relationship is that China has lost its 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 costs. 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 high labor cost pushed multinationals leaving China to other low labor cost countries, leading the share of processed and assembly exports in total exports decreased from 55% in 2005 to 36% in 2015 on the one hand<sup>4</sup>. It reduced profit margins on the other hand which obligated Chinese processing and assembly exporters making great effort by eliminating excess labor or by introducing labor saving techniques to increase efficiency in production, which is favorable to the productivity of 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).

Moreover, China's GVC participation has optimized resource reallocation of production factors inside manufacturing sectors towards those which are more productive, leading the rise of manufacturing productivity on average. This is for example the case of computer,

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<sup>2</sup> 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 re-exporting.

<sup>3</sup> Manufacturing labor productivity is calculated as ratio of real domestic value added of 15 manufacturing industries except for coke and refined petroleum sector (2010=100) divided by number of employee. Fig 1a and 1b in section 3 show the negative statistical relationship between GVC backward linkage and productivity for 15 manufacturing industries over the 2005-2014 period at national and sector levels. Author's calculation according to OECD TiVA and WIOD databases.

<sup>4</sup> China-United States trade war and reindustrialization of developed countries because of Covid-19 crisis are among other reasons for the recent moving out of multinationals from China.

electronic and optical products sector which has the highest share of foreign value added and the highest productivity growth, and became the biggest sector. This 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 measure magnitude of each sector relative to others and productivity (OECD, 2018),<sup>5</sup> which is rarely studied in GVCs literature.

Finally, the high labor cost pushed assembly and processing exporters either to import core technologies to develop their own higher value added brand able to compete in world market with successful example of mobile phones such as Huawei, OPPO and Xiaomi among the top five global smartphone brands; or obligated others to buy locally produced varied but less expensive intermediate goods to produce their final exports. This import substitution by domestic ones is possible thanks to the expansion of local firms now able to produce relatively higher value added intermediate goods available to local firms or to export to third countries after a longue period of learning by doing from multinationals since China's open door policies in 1979 (Kee and Tang, 2016; Chor et al., 2021). The share of Chinese intermediate goods embodied in exports of third countries relative to gross exports, named forward linkages, 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, increased thus productivity.

To verify the above arguments, we estimated the impacts of Chinese GVC participation on productivity by using panel data of 15 manufacturing industries over the 2005-2014 period with OECD TiVA and WIOD databases<sup>6</sup>. In order to compare to previous studies, we began to estimate a simple reduced-form model to investigate the impact of GVC backward and forward linkages on productivity by controlling time and industry fixed effects as Kummritz (2016) and Urata and Baek (2020), and we extended this investigation to GVC participation and position indices. GVC position index allows capturing effect of moving up on productivity. We obtained a negative coefficient of sector level GVC backward linkages relative to sector's exports 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 sector level share of foreign value added in exports relative to China's gross exports,

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<sup>5</sup> Fig. 1c section 3 shows a positive relationship between structure backward linkages and productivity.

<sup>6</sup> We have excluded the petroleum sector because of its special characters. Moreover this sector is under the state control in China.

confirming the positive resource allocation effects in favor of more productive sectors. We find moreover that China's GVC forward linkage and position indices exerted positive impact on productivity, while the effect of GVC participation is statistically insignificant probably due to the opposite effects of backward and forward linkages<sup>7</sup>.

We made several robustness tests to verify the stability of the above baseline results. First, bias resulting from omitted variables is a major obstacle in empirical macroeconomic literature on trade and growth. Even that the estimations at industrial levels with time and sector fixed effects allow capturing common factors for GVC participation indices and productivity and thus mitigate bias, it is necessary to 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 particularly marked in the industrial sector during the first period of China's open door policies in 1979. We followed Kordalska et al. (2016), Constantinescu et al. (2017), Yu and Lou (2018), Gal and Witheridge (2019), Montalbano and Nenci (2020) etc. to estimate a GVC augmented production function which allows us to add capital intensity into the baseline function. Secondly, we followed Constantinescu et al. (2019) to add non GVC related trade variables which may exert productivity effects through enhanced competition via imports at the same stage of production, greater access to better-quality or more-diverse imported inputs (Amiti and Konings 2007; Goldberg et al. 2010) or through learning by exporting (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. We added real exchange rate into the baseline equation to control the effects.

An issue arising from estimating the above models is potential endogeneity bias. A reverse causal relationship, i.e. an industry with high productivity growth is easier to be engaged in GVCs, is possible (Del Prete et al., 2017; Urata and Baek, 2021). We followed Banh et al. (2021) to use the average GVC indices at world level as instrumental variables (IV) to estimate the effects of China's GVC participation on its labor productivity. The instrumentation supposes that the driving forces of GVC participation are the same for China and for the world. It is probably the case. 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 confirm that the positive productivity effect of China's GVCs participation resulted from optimizing resource allocation inside backward linkages

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<sup>7</sup> See table 1 for the econometric results.

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 leading a structural transformation in manufacturing industry.

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 (Ignatenko et al., 2019). This study completes this gap by estimating the impact of GVCs on sectoral manufacturing productivity in China. 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 advantage for using GVC position index is to capture GVC moving up effect on productivity. 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 via structural transformation to avoid being entrenched in low-profitability low productivity growth GVC activities (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, thus improve productivity, while the literature ignored this effects. This study extended the literature on the effects of China's GVC participation, which focused on domestic value added in exports (Kee and Tang, 2016; Yu and Luo, 2018; Taguchi and Li; 2018; Hua, 2022 etc.), or productivity at firm level (Lu et al., 2016 and 2018; Ge et al. 2018; Chor et al., 2021). This study also 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, 2001).

The rest of this paper is organized as following. Section 2 provides a literature review. Section 3 presents a model to estimate the impact of GVC participation on productivity in China. Section 4 presents econometric tests and results. The political and economic implications are given in the conclusion.

## **2. Literature review**

Recent theoretical literature argues positive impacts of global value chains participation on productivity improvement through a myriad of channels (Criscuolo and Timmis, 2017). These positive impacts pass through finer international division of labor inside a global value chain according to comparative advantage of each country which acts as

factor-augmenting technical change, increases efficiency inside a globalized system of production and thus generates productivity gains (Grossman and Rossi-Hansberg, 2008; Baldwin, 2012). GVC gives opportunities for developing countries without a whole production line to participate in a globalized system of production, to access to differentiated variety and higher-quality foreign intermediate goods and foreign services (Gereffi et al., 2005; Giuliani et al., 2005; Kowalski et al., 2015; Pahl & Timmer, 2019). The interaction with multinationals gives incentives to innovate and adopt foreign technologies to match international standards and benefit from learning externalities and technology spillovers, and thus increase efficiency (Pietrobelli and Rabellotti, 2011; Kawakami et al., 2012; and Baldwin and Robert-Nicoud, 2014). The engagement in higher quality export activities in world market encourages developing countries to diversify and to upgrade towards new and higher value added activities improving thus productivity (Li and Liu, 2014; Ndubuisi and Owusu, 2021).

Gains from GVC participation are not automatic and depend on position in global value chains according to comparative advantages of developing countries (Ignatenko et al., 2019). Linking into global value chains via backward linkages is not enough for taking gains in long terms, moving up towards higher value added forward linkages along to the rise of labor cost is necessary to increase productivity (Banga, 2014). There is a risk for developing countries to be forced to specialize in low-productivity low cost tasks, and thus bad for their industrialization and productivity (Dalle et al.; 2013 and UNCTAD, 2013; Jean et al., 2020). Thus, the impact of GVC backward linkages on productivity growth is ambiguous, necessitates an empirical investigation.

The empirical studies on productivity impact of GVCs are emerging using either micro firm level or macro country industry level. Firm level studies are often made for a country due to data limitations on tracking the flow of inputs and outputs across firms at international level, while macro level analysis uses GVC participation indices based on international input output tables (Koopman et al., 2014; Banh et al., 2020). This study belongs to macro analysis.

Concerning firm level studies, using Canada's Annual Survey of Manufactures data for the 2002-2006 period, Baldwin and Yan (2014) found positive impact of firm's GVC participation on labor productivity. Del Prete et al. (2017), using World Bank Enterprise Surveys data for Egypt and Morocco in 2004 and 2007, found that firms entering GVCs perform better selection effect, and obtain additional productivity gain ex-post. Using the Chinese Industrial Firm Database and China Customs Import and Export Database, Lu et al. (2016; 2018) found an inverted U-shaped non-linear relationship between GVC backward



participation of Chinese firms and their TFP for 2000 to 2006 period and that Chinese manufacturing enterprises' GVC participation improved significantly their productivity for 2000-2007 period. Benkovskis et al. (2020) found positive effect of exports of intermediate goods, re-exports, and service exports on Latvian firms' productivity over the 2006–2014 period, and for Estonian firms over the 1995–2014 period. Using 17 manufacturing sectors in 2009 and 2015 in Indonesia, the Philippines, and Viet Nam, Urata and Baek (2021) found a positive effect of GVCs only for Indonesian firms importing intermediate goods to export, but not for the Philippines, and Viet Nam.

The studies using multi countries industries panel data often included developed and developing countries and used inter-country input-output tables from World Input-Output Database. Two papers used reduced form model to estimate the effect of GVC participation on productivity growth. Kummritz (2016), using panel data of 20 industries and 54 countries covering 1995, 2000, 2005, and 2008–2011, found that a 1% increase in sector level forward linkages leads to 0.33% higher industry-level labor productivity, while the effect of backward linkages is not statistically significant. He also found that both backward and linkage linkages at county level are statistically significant with estimated coefficients of 0.46 and 0.80. Urata and Baek (2020) followed Kummritz to estimate reduced form model by using panel estimation covering 47 countries and 13 manufacturing sectors for 1995–2011, and found that both sector level backward and forward GVC participation increased TFP growth with a larger effect for backward participation for developing countries. Other studies are based on a GVC augmented production function. Using panel data on trade in value-added covering 20 sectors of which 13 manufacturing sectors in 40 countries over 1995-2011 period, Kordalska et al. (2016) estimated an augmented production function in which foreign value added content of exports are considered as potential technology shifters, i.e. as determinants of the technological change term. They found that sector level foreign value added share in gross exports of industry increased sectoral productivity growth, but only for manufacturing sectors. Using panel data of 13 manufacturing industries in 40 countries over 1995 to 2009 period, Constantinescu et al. (2019) found that backward participations in GVCs measured as share of foreign value added in gross exports exert significant positive effects on labor productivity. Yanikkaya and Altun (2019), using panel data over 1995-2014 for 54 countries, found that higher backward participation reduced TFP growth, while higher forward participation raises TFP growth. They also found significant positive results for backward and forward participation only for developed countries, and concluded that developing countries do not able to benefit from participating in export value chains either backwardly or forwardly.

Battiati et al. (2020), using panel data of 12 European countries and the US for 30 industries over the years 2000-2014, found a statistically significant impact of forward and backward participation on productivity growth and that the effect of forward linkages is higher in the digital sectors. Banh et al. (2020), using industry-level data from 2000 to 2016 in Estonia, found that higher GVC participation significantly boosts productivity, but its participation of downstream industries has a negative impact on productivity.

### **3. impact of GVC participation on productivity in China**

This section proposes several models to be estimated after an analysis of statistical relationship between four GVC participation and productivity.

#### **3.1. Statistic relationship between GVC participation and productivity**

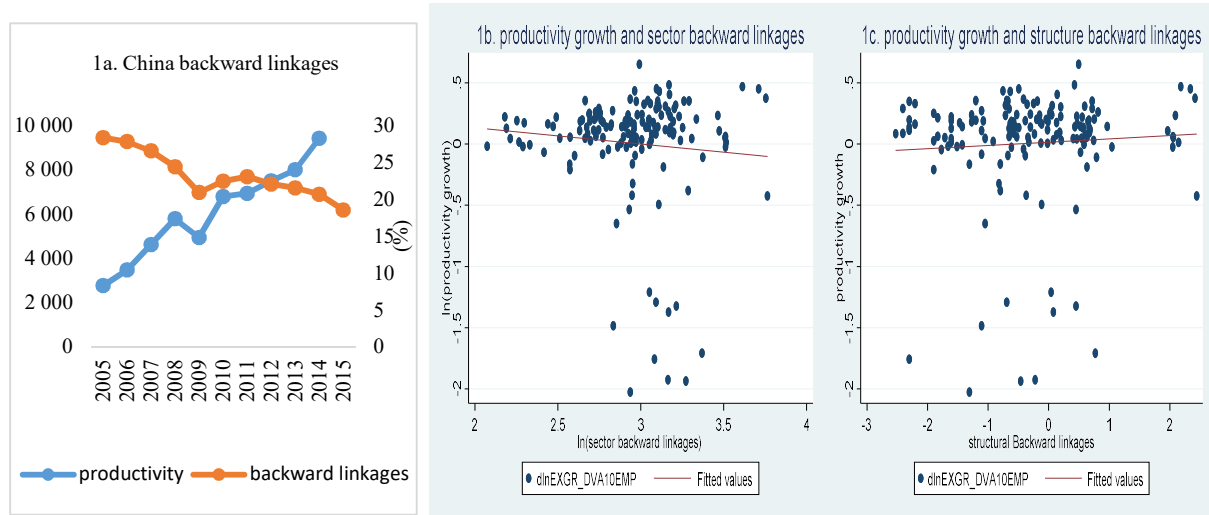
As explained in the introduction, this study is motivated by observing a negative statistical correlation between either the share of China's foreign value added relative to China's gross exports (named here as China's backward linkages), or the share of sector's foreign value added relative to sector's exports (named sector backward linkages), and productivity over the 2005-2014 period for 15 Chinese manufacturing industries (Fig. 1a, 1b). China's and sector's backward linkages measure the intensity of FVA in a country's and an industry's exports. They are largely used in the literature to estimate their effects on productivity. Their negative relationships with productivity suggest that the more foreign value added embodies in backward linkages activities, the less productivity is, suggesting that the high rise of labor cost pushed multinationals delocalizing their firms to other countries and forced Chinese firms improving efficiency.

As argued in the introduction, it is possible that the productivity improvement results from the fact that GVCs participation optimizes resource allocation inside industries towards more efficiency ones, leading structural transformation. This effect can be captured by the sector's share of foreign value added in exports relative to China's gross exports (named here structure backward linkages) measuring the magnitude of an industry compared to other industries (OECD, 2018). We observe effectively a positive statistical relationship between structure backward linkages and productivity (Fig 1c). Structure backward linkages are rarely used to capture the effect of resource allocation on productivity.

These simple statistical correlations do not take into account other factors which are susceptible to influence productivity. We make econometric investigations to test the effects of Chinese backward linkages on productivity, but also to estimate the effects of three other

GVC participation indices such as forward linkages, participation and position indices on productivity.

Fig. 1. Relationship between labor productivity and GVC 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/or sector's domestic exports relative to China's/sector's gross exports. Structure backward linkage is calculated as the share of foreign value added embodied in sector's domestic exports relative to China gross exports. Industry and year fixed effects are controlled in Fig. 1b and 1c.

Source: OECD TiVA and WIOD databases.

### 3.2. Econometric model of impact of GVC on productivity

We test the productivity effects of GVC backward linkages and extend it to other GVCs participation indices such as forward linkages, participation and position indices. To estimate the impact of industrial level GVCs participation relative to an industry's exports on productivity, we follow the studies of Kummritz (2016) and Urata and Baek (2020) to use a simple reduced-form model such as:

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

Where  $LP_i$  is labor productivity in sector  $i$ , GVC represents respectively backward, forward, participation and position indices relative to sector's exports.  $i$  represents manufacturing sectors,  $t$  years.  $\mu_i$  captures fixed sector effects,  $\pi_t$  captures year-fixed effects,  $\varepsilon_{it}$  is error terms. Year and sectoral 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

their coefficients are interpreted as elasticities.  $a_1$  is the key coefficient of our interest. The sign of  $a_1$  is waited negative for backward linkages as suggested in Fig. 1a and 1b, while 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 the following equation :

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

Where  $FVA\_SH_{it}^2$  represents sector backward linkages in square form. A statistically significant and negative sign of  $a_2$  suggests that the effect of GVCs backward linkages on productivity is positive in first period and is reversed in the second period. We can calculate turning point to check the position of industries during the studied period.

To estimate the effects of GVC structure backward linkages participation, we replace sector  $GVC_{it}$  by structure backward linkage  $DVC_{it}$  as following

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

Where  $GVC_{it}$  respectively represents structure level GVC backward, forward, participation and position indices relative to China's exports. The coefficient of  $b_1$  is waited positive as suggested Fig. 1C in section 3.1.

#### 4. Empirical analysis

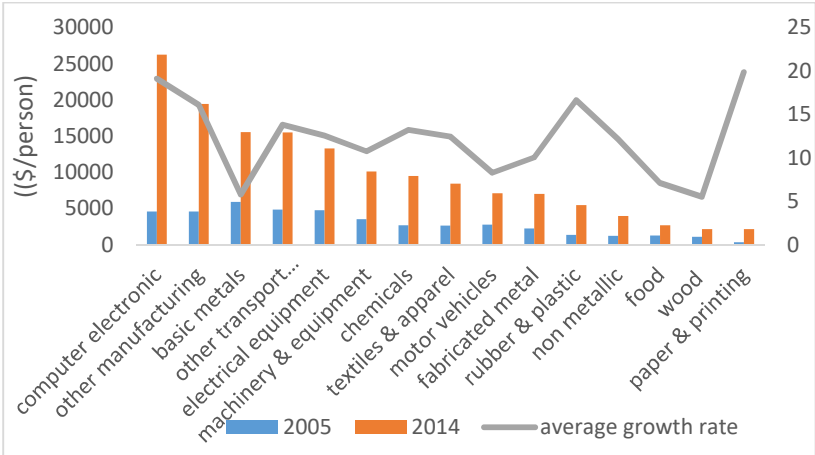
The above equations are estimated for 15 manufacturing industries over the period from 2005 to 2014 using OECD TiVA and WIOD databases (see table annex 1 for the list of sectors). The analysis period and the sample size are determined by data availability from the OECD Trade in Value Added (TiVA) and World Input-Output Database (WIOD) databases. The OECD TiVA publishes data over the period from 2005 to 2015 for 16 manufacturing sectors (2018 edition). 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 industry-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 the sources of data are the following and resumed in table Annex 2.

**4.1. Definitions and sources of variables**

Labour 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. Fig 2 shows the evolution of labor productivity over the 2005-2014 period. The labor productivity in computer & electronic 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 had the smallest productivity which increased from 379 \$/person in 2005 to 2185 \$/person in 2014, but increased at the highest average annual growth rate of labor productivity (19.9%). 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%. 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.

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



Sector GVC backward linkage is measured as share of foreign value added embodied in sector i (FVA<sub>ij</sub>) relative to gross exports of industry i (EXGR<sub>ij</sub>) as such:

$$\text{Sector GVC backward linkage: } FVA\_SHiit = \frac{FVAit}{EXGRit} * 100$$

Sector GVC backward linkage captures the share of imported intermediate goods embodied in a domestic industry from foreign industry upstream in global production chain, and thus measures the intensity of foreign value added or import content in an industry's exports. A high share of sector backward linkage indicates that the industry mainly engages in final assembly of imported inputs from other countries by participating in cross-country production sharing on the low end of GVC and thus strongly depends on the rest of the world. A decreasing value signifies that industry moves up from final stage of global value chains to higher productivity sector. China's share of backward linkages decreased of 3.4% per year on average over 2005-2014 period. It suggests that Chinese manufacturing industry is moving up.

Fig 3a shows the evolution of sector backward linkages for 15 Chinese manufacturing industries in 2014 relative to 2005. The share of foreign content relative to exports decreased by 9.6 percentage points from 26.3% in 2005 to 16.6% in 2014. It decreased for all sectors. 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% 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 (Fig 3a).

Structure GVC backward linkage is measured as share of foreign value added embodied in sector *i* ( $FVA_i$ ) relative to China's gross exports ( $EXGR_c$ ) such as:

$$\text{Structure GVC backward linkage: } FVA\_SHict = \frac{FVAit}{EXGRct} * 100$$

Structure GVC backward linkage captures the share of imported intermediate goods embodied in sector *i* from foreign industry upstream in global production chain relative to China's exports, and thus measures the magnitude of an industry relative to other sectors (OECD, 2018). A high share indicates the concentration of foreign value added in an industry relative to others. In China, the ICT & electronic sector is the most important sector participating GVCs backward linkage activities relative to other industries 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 2<sup>nd</sup> place in 2014 was replaced by electrical equipment sector whose share decreased from 2.1% in 2005 to 1.9% in 2014.

Forward linkage (DVAFX\_SH) is calculated as share of domestic value added embodied in intermediate exports that are further re-exported to third countries either relative to gross exports of industry  $i$  or relative to China's gross exports such as:

$$\text{GVC sector forward linkage: } DVAFX\_SH_{iit} = \frac{DVAFX_{it}}{EXGR_{it}} * 100$$

$$\text{GVC structure forward linkage: } DVAFX\_SH_{ict} = \frac{DVAFX_{it}}{EXGR_{ct}} * 100$$

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 country 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 (Wang et al. 2014). It reflects the dependence of the rest of the world on the country.

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 increased the quickest for the ICT & electronic sector, which passed from 27% in 2005 to 32% in 2014, while it decreased 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 & electronic sector has the most important share in structure forward linkages which decreased from 4.4% in 2005 to 3.4% in 2013, following by motor vehicles whose share increased from 1.5% to 1.9%.

GVC participation is the sum of forward and backward linkages such as:

$$\text{GVC sector participation: } GVCPart_{iit} = \frac{FVA_{it} + DV_{it}}{EXGR_{it}} * 100$$

$$\text{GVC structure participation: } GVCPart_{ict} = \frac{FVA_{it} + DVA_{it}}{EXGR_{ct}} * 100$$

It measures the extent to which an industry is involved in the global production chain. The larger the ratio, the greater the intensity of involvement of an industry in a country in GVCs. Sector GVC participation in all sectors decreased 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.

GVC position is measured as the log ratio of an industry's supply of intermediates used in other countries' exports to the use of imported intermediates in its own production either relative to sector exports or to China exports as following:

$$\text{sector GVA position}_{it} = \ln\left(1 + \frac{DVAFX_{it}}{EXGR_{it}}\right) - \ln\left(1 + \frac{FVA_{it}}{EXGR_{it}}\right)$$

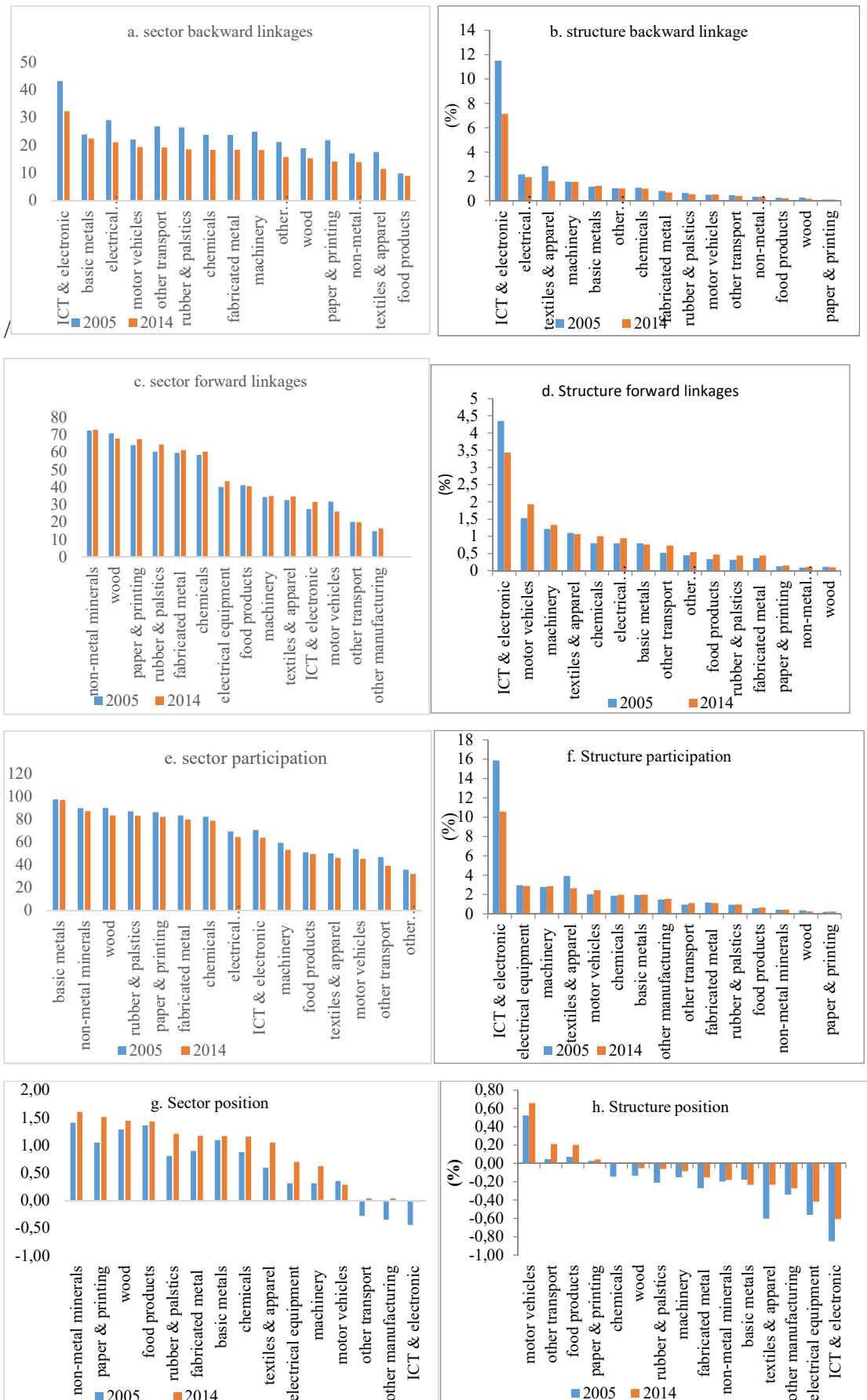
$$\text{structure GVA position}_{ict} = \ln\left(1 + \frac{DVAFX_{it}}{EXGR_{ct}}\right) - \ln\left(1 + \frac{FVA_{it}}{EXGR_{ct}}\right)$$

This index characterizes the relative upstreamness of an industry to gauges whether an industry is likely to be in the upstream or downstream of the global value chain (GVC) (Koopman et al., 2014). A positive index means that countries 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. It allows knowing if there is an effect of moving up.

All industries had positive sector position indices 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 & electronic sector was still negative in 2014, meaning that this sector imported more intermediate goods to produce final goods. Even still lightly negative, ICT & electronic 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.



Figure 3. Evolution of GCVs participation indices for 15 Chinese manufacturing sectors



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 in industry  $i$  deflated by industrial price. Real imports of final products are calculated as nominal imports of final products in industry  $i$  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.

## **4.2. Econometric tests and results**

### **4.2.1. Econometric tests**

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). 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 labour 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 GVP 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 2SLS estimation is confirmed by the results of underidentification 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).

#### **4.2.2. Results of baseline estimation**

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 industry 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 VI instruments. The coefficient of sector backward linkages is negative and statistically significant (-2.36, column 1.6 part 1). As the share of foreign value added relative to exports at sector level decreased over the 2005-2014 period, Chinese GVC backward linkage contributed productivity improvement by moving out from processing and assembly exports. The annual average contribution of GVC backward linkages to productivity can be calculated as the product of the coefficient of 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, all manufacturing industries are positioned on the decreasing trend. As waited, the coefficient of structure backward linkages is positive and statistically significant (0.48). 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 (Table 2).

The result shows a positive coefficient for sector GVC forward links which is estimated to 2.14 (Column 1.6, 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 labour 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. 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 GVC backward and 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 contributing to improve GVC position from 0.3 in 2005 to 0.7 in 2014 at sector level and at structure level.

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

	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*** (-7.04)	3.36*** (2.95)				-2.36*** (-5.32)	3.50** (2.11)			
GVC sector backward linkages <sup>2</sup>		-0.87*** (-4.57)					-0.97*** (-3.77)			
GVC sector forward linkages			2.12*** (6.27)					2.14*** (3.90)		
GVC sector participation				-0.61 (-0.91)					-1.69 (-1.32)	
GVC sector position					1.39*** (8.56)					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 <sup>2</sup>	0.85	0.87	0.86	0.82	0.84	0.85	0.89	0.86	0.81	0.87
	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-Paap rk 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 <sup>2</sup>	0.85	0.85	0.85	0.88	0.85	0.85	0.84			0.88

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

	Estimated coefficients	Annual average growth rates	Annual average contributions
	a	B	c=a*b
Sector backward linkages	-2.36	-3.36	7.93
Structure backward linkages	0.48	-3.17	-1.52
<b>Total</b>			<b>6.41</b>
Sector forward linkages	2.14	0.95	2.03
Structure forward linkages	0.57	-0.10	-0.06
<b>Total</b>			<b>1.97</b>

Source: Authors' calculation

## 5. Robustness tests

We make several robustness tests to verify the stability of the baseline results. 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:

$$\ln LP_{it} = a_0 + a_1 \ln GVC_{it} + a_2 \ln \left(\frac{K}{L}\right)_{it} + \mu_i + \pi_t + \varepsilon_{it} \quad (4)$$

The equation 5 allows us to test if the omission of capital intensity variable biased the baseline results obtained in equation 1.

The underlining hypothesis of equations 1 and 5 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 2 such as

$$\ln LP_{it} = a_0 + a_1 \ln GVC_{it} + a_2 \ln \left(\frac{K}{L}\right)_{it} + a_3 \ln X_{it} + a_4 \ln M_{it} + \mu_i + \pi_t + \varepsilon_{it} \quad (5)$$

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.

$$\ln LP_{it} = a_0 + a_1 \ln GVC_{it} + a_2 \ln \left(\frac{K}{L}\right)_{it} + a_3 \ln RER_{it} + \mu_i + \pi_t + \varepsilon_{it} \quad (6)$$

The obtained results 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 2.8, part 2, table 2). 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 3.8, part 3, table 1). 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 4.8, part 3, Table 2).





Table 2. Impact of GVCs on labor productivity of 15 manufacturing sectors 2005-14, robustness tests

Part 1 Capital intensity								
Equation 2	2.1	2.3	2.4	2.5	2.6	2.8	2.9	2.10
Backward linkages	-1.74*** (-7.00)				-2.35*** (-527)			
Forward linkages		2.18*** (6.44)				1.98*** (3.95)		
GVC participation			-0.60 (-0.88)				-1.84 (-1.17)	
GVC position				1.44*** (7.71)				2.02*** (5.80)
Capital intensity	-0.05 (-0.44)	-0.19 (-1.49)	-0.08 (-0.52)	0.09 (0.72)	-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 <sup>2</sup>					0.85	0.86	0.81	0.87
Part 2 non GVCs related trade								
Equation 3	3.1	3.3	3.4	3.5	3.6	3.8	3.9	3.10
Backward linkages	-1.21*** (-5.95)				-1.73*** (-3.69)			
Forward linkages		1.78*** (7.60)				1.46*** (4.62)		
GVC participation			0.22 (0.45)				0.22 (0.25)	
GVC position				0.98*** (6.50)				1.27*** (4.92)
Capital intensity	0.14 (1.55)	0.04 (0.51)	0.14 (1.32)	0.22** (2.53)	0.14 (1.21)	0.09 (0.84)	0.19 (1.47)	0.05 (0.48)
Real exports of final products	0.80*** (9.10)	0.88*** (11.5)	1.03*** (11.36)	0.79*** (9.32)	0.71*** (6.59)	0.93*** (11.7)	1.01*** (9.42)	0.77*** (10.2)
Real imports of final products	0.07 (1.11)	0.04 (0.71)	-0.08 (-1.22)	0.04 (0.74)	0.13 (1.36)	-0.11 (-1.26)	-0.16 (-1.55)	0.01 (0.18)
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 <sup>2</sup>					0.91	0.94	0.92	0.94
Part 3 real exchange rate								
Equation 4	4.1	4.3	4.4	4.5	4.6	4.8	4.9	4.10
Backward links	-1.43***				-1.87***			

	(-5.82)				(-4.28)			
Forward linkage		1.87*** (5.57)				1.72*** (3.82)		
GVC participation			-0.30 (-0.48)				-1.21 (-0.89)	
GVC position				1.20*** (6.40)				1.89*** (5.69)
Capital intensity	0.12 (0.98)	0.03 (0.27)	0.18 (1.29)	0.22* (1.86)	0.10 (0.70)	0.05 (0.33)	0.18 (1.25)	-0.04 (-0.25)
Real exchange rate	0.58*** (4.02)	0.67*** (4.74)	0.82*** (5.34)	0.53*** (3.76)	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	11.95							
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 <sup>2</sup>					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.



## 6. Conclusion

The objective of this study is to estimate the impact of Chinese GVC participation on productivity by using panel data of 15 manufacturing industries over the 2005-2014 period. We find that the obtained negative coefficient of sector backward linkage together with its decreased growth rate increased productivity, but slightly mitigated by the negative contribution of structure backward linkage calculated as the product of the positive coefficient optimizing resource allocation inside industries multiplied by its decreased growth rate. We find that the positive coefficient of sector forward linkage together with its positive growth rate contributed to increase productivity, which is slightly alleviated by the negative contribution of structure forward linkages measured as the product of the positive coefficient multiplied by its negative growth rate. We find finally that GVCs position improvement contributed to productivity growth. The Chinese experience shows that the structural transformation and moving up along with the rise of labor cost is essential to keep high productivity and to reduce the risk of being stuck in low-value-added tasks and to industrialize.

We observe that the contribution of GVCs backward linkages to labor productivity improvement mainly passed through moving out low labor cost sectors, and 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 complicated and sophisticated technological content is more complicated, while China has lost comparative advantages in backward linkage intensive in labor costs. We observe that, despite the sensible improvement, the GVC position of ITC and electronic is still negative and situated in the end of chains, depending thus more foreign countries than the last ones depend on China. The trade war between China and USA and Covid-19 crisis have increased trade protection and will make the GVC position improvement much more difficult. The emphasis on research and development (R&D) will be essential to keep productivity growth.

This study is limited to manufacturing sector. Future research may extend the analysis to identify the channels through which China's GVC participation impacts productivity, in particular the effects of the participation of services industries in GVCs etc. It may extend the analysis to explore other economic and social effects.

## References

- Aqib A., N. Novta, F. Rodrigues-Bastos (2017) Calculating Trade in Value Added, July 31. Working Paper No. 17/178, International Monetary Fund.
- Assche A. V. (2018) Functional upgrading in China's export processing sector, *China Economic Review*, vol. 47, issue C, 245-262.
- Baldwin, R., and B. Yan. (2014). "Global value chains and the productivity of Canadian manufacturing firms." *Economic Analysis Research Paper Series No. 90*.
- Baldwin R. (2016). *The Great Convergence, Information Technology and the New Globalization*, Harvard University Press. *Economic Policy*, 28(2), 211-234.
- Banga, R. (2014) "Linking into global value chains is not sufficient: Do you export domestic value contents," *Journal of Economic Interaction and Coordination*, 29(2), 267-297.
- Banh H T., P Wingender and C. A. Gueye (2020) *Global Value Chains and Productivity: Micro Evidence from Estonia*. IMF Working Paper, WP/20/117.
- Battiati C., C. Jona-Lasinio and S. Sopranzetti (2020) *Productivity growth and global value chain participation in the digital age*, ESCoE Discussion Paper No. 2020-04, April.
- Benkovskis, K., J. Masso, O. Tkacevs, P. Vahter, and N. Yashiro. (2020). "Export and productivity in global value chains: Comparative evidence from Latvia and Estonia." *Review of World Economics*, 156, 557–577.
- Borin, A. and M. Mancini. 2019. *Measuring What Matters in Global Value Chains and Value-Added Trade*. Policy Research Working Paper; No. 8804. World Bank, Washington, DC.
- Chen, Q., Gao, Y., Pei, J., de Vries, G., & Wang, F. (2018). *Formerly Assembled, But Now Designed in China? Assessing the Domestic Value-Added of Activities in Gross Exports*. (GGDC Research Memoranda; Vol. GD-180). GGDC
- Chor D., K. Manova, Z. H. Yu (2021) *Growing like China: Firm performance and global production line position*, *Journal of International Economics*, 130, 103445.
- Constantinescu, C., Mattoo, A. and Ruta, M. (2019), *Does vertical specialization increase productivity?* *The World Economy*, 42(8), 2385-2402.
- Costinot A., Vogel J. and Wang S. (2013) *An Elementary Theory of Global Supply Chains*. *Review of Economic Studies*, 80, 109-144.
- Crisuolo, C. and Timmis, J. (2017). *The Relationship Between Global Value Chains and Productivity*. *International Productivity Monitor*, 32:61–83.

- Dalle, D., V. Fossati, and F. Lavopa (2013). Industrial policy and developmental space: The missing piece in the gvcs debate. *Revista Argentina de Economía Internacional* December 2.
- Del Prete, D., G. Giovannetti, and E. Marvasi. (2017). "Global value chains participation and productivity gains for North African firms." *Review of World Economics*, 153(4), 675–701
- Duan Y.W., E. Dietzenbacher, X. M. Jiang, X.K. Chen & C.H. Yang (2018) Why has China's vertical specialization declined?, *Economic Systems Research*, 30:2, 178-200.
- Gal, P. and Witheridge, W. 2019. Productivity and innovation at the industry level: What role for integration in global value chains?, *OECD Productivity working papers*. No 19, October.
- Ge J., Y. Fu, R. Xie, Y. Liu, W. Y. Mo, (2018) The effect of GVC embeddedness on productivity improvement: From the perspective of R&D and government subsidy, *Technological Forecasting and Social Change*, 135, October, 22-31.
- Gereffi G., Humphrey J. and Sturgeon T. (2005) The Governance of Global Value Chains, February, *Review of International Political Economy* 12(1):78–104-78–104 DOI:10.1080/09692290500049805.
- Grossman, G. M., and E. Rossi-Hansberg. 2008. "Trading Tasks: A Simple Theory of Offshoring." *American Economic Review*, 98 (5): 1978-97.
- Guillaumont Jeanneney and Hua (2011) How does real exchange rate influence labour productivity in China? *China Economic Review*, Volume 22, Issue 4, December, Pages 628-645.
- Hummels D., Ishii J., Yi K, 2001, The nature and growth of vertical specialization in world trade, *Journal of International Economics*, 54, 75-96.
- Humphrey, J. and Schmitz, H., 2002. How does insertion in global value chains affect upgrading in industrial clusters?. *Regional studies*, 36(9), pp.1017-1027.
- Ignatenko, A., Raei, F., B. Mircheva (2019). "Global Value Chains: What are the Benefits and Why Do Countries Participate?", *IMF Working Paper No: WP/19/18*.
- Johnson, R. C. and G. Noguera (2017). "A Portrait of Trade in Value Added over Four Decades." *The Review of Economics and Statistics*, vol. 99(5), pp. 896-911.
- Kawakami, M., T. J. Sturgeon (2011) *The Dynamics of Local Learning in Global Value Chains, Experiences from East Asia*, Palgrave Macmillan edition.
- Kee, H. L. and H. Tang (2016). "Domestic Value Added in Exports: Theory and Firm Evidence from China." *American Economic Review*, vol. 106(6), pp. 1402-1436.

- Koopman, R., R.Z. Wang and S-J Wei (2012), "Estimating Domestic Content in Exports When Processing Trade is Pervasive," *Journal of Development Economics*, 99 (1), 178-189.
- Koopman, R., Z. Wang, and S. J. Wei. (2014). "Tracing Value-Added and Double Counting in Gross Exports." *American Economic Review*, 104 (2): 459-94. DOI: 10.1257/aer.104.2.459
- Kordalska, A., J. Wolszczak-Derlacz, and A. Parteka. (2016). "Global value chains and productivity gains: A cross-country analysis." *Collegium of Economic Analysis Annals*, 41, 11–28
- Kummritz, V. 2016. "Do Global Value Chains Cause Industrial Development?," CTEI Working Papers series 01-2016, Centre for Trade and Economic Integration, The Graduate Institute.
- Kummritz, V., D.Taglioni, D.Winkler 2017. *Economic Upgrading through Global Value Chain Participation: Which Policies Increase the Value Added Gains? Policy Research Working Paper, No 8007*. World Bank, Washington, DC.
- Lu, Y., S.L. Sun, and Y. Chen. (2016). "Global value chain embeddedness and latecomer's productivity: Examining the springboard perspective." *National University of Singapore, GPN Working Series Paper*, 9.
- Leng S. (2018) "China's once-booming textile and clothing industry faces tough times," *South China Morning post*, 30 April 2018.
- Linden, G., K. L. Kraemer, and J. Dedrick, (2011). *Innovation and Job Creation in a Global Economy: The Case of Apple's iPod*. *Journal of International Commerce and Economics*, 3, 223-239.
- Meng, B., Z. Wang, R. Koopman (2013). "How are Global Value Chains Fragmented and Extended in China's Domestic Production Networks? IDE Discussion Paper No. 424.
- Meng, B., Y. Fang, J. Guo, Y. Zhang (2017). "Measuring China's domestic production networks through trade in value-added perspectives." *Economic Systems Research*, vol. 29(1), pp. 48-65.
- Montalbano P. and S. Nenci (2020) "The effects of global value chain (GVC) participation on the economic growth of the agricultural and food sectors." *Background paper for The State of Agricultural Commodity Markets (SOCO) 2020*, FAO.
- Ndubuisi G. and S. Owusu (2021) *How important is GVC participation to export upgrading?*, *The World Economy*, 00:1–22.

- Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015), "An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production", *Review of International Economics.*, 23: 575–605
- Pahl S. & Marcel P. Timmer (2020) Do Global Value Chains Enhance Economic Upgrading? A Long View, *The Journal of Development Studies*, 56:9, 1683-1705, DOI: 10.1080/00220388.2019.1702159
- Pietrobelli C. and R. Roberta Rabellotti (2011) Global Value Chains Meet Innovation Systems: Are There Learning Opportunities for Developing Countries? *World Development*, vol. 39, issue 7, 1261-1269
- Taguchi H. and J. Li (2018) Domestic value creation in the involvement in global value chains: the case of Chinese economy, *Asian Development Policy Review*, DOI: 10.18488/journal.10
- Tajoli, L., Felice, G. (2018) Global Value Chains Participation and Knowledge Spillovers in Developed and Developing Countries: An Empirical Investigation. *The European Journal of Development Research*, 30, 505–532.
- UNCTAD (2013). *World investment report 2013: Global value chains: Investment and trade for development*. Technical report, United Nations Publication, Geneva
- Urata, S., and Baek, Y. (2020). Does participation in global value chains increase productivity? an analysis of trade in value added data. *Thailand and the World Economy*, 38(1), 1-28.
- Urata, S. and Y. Baek. (2021). Does GVC Participation Improve Firm Productivity? A Study of Three Developing Asian Countries. ADBI Working Paper 1245. Tokyo: Asian Development Bank Institute. Available: <https://www.adb.org/publications/does-gvcparticipation-improve-firm-productivity>
- Yanikkaya, H. and A. Altun (2018). “The Impact of Participation in Export Value Chains on TFP Growth”, *Ege Academic Review*, 19(1), 119-129.
- Yu C. J. and Z. C. Luo (2018) *China Economic Review*, What are China's real gains within global value chains? Measuring domestic value added in China's exports of manufactures, Volume 47, February 2018, Pages 263-273.



**Table Annex 1: 15 Manufacturing industry classification**

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

**Table Annex 2. 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 value-added price (2010=100) and divided by numbers of employees	OECD TiVA; World Input-Output 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.