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Free trade agreements partnership and value chain linkages: Evidence from China

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Abstract

As multilateral trade negotiations have lapsed into stalemate, regional economic integration arrangements like free trade agreements (FTAs) are gaining growing prominence. We propose a theory on how a developing country's GVC linkages with partners are affected by partners' position on the GVCs and the characteristics of the FTAs, and use a large matched data of China's trading partners to validate our hypothesis. We find that there are stronger value chain linkages between China and higher-income economies, and the degree of mutual value chain dependence rises in line with the partner's development level. The GVC promoting effect of FTA partnership is more pronounced for China's value chain linkages with its higher-income partners. The results survive various robustness checks and are likely to be informative for other developing countries.

KEYWORDS

backward and forward linkages, free trade agreement, global value chains, input–output analysis

1 | INTRODUCTION

The past 30 years have witnessed the proliferation of preferential trade and investment liberalisations. More than 400 regional free trade agreements (FTAs) are currently in force, covering most economies in the world. The expansion of FTA is even not hampered by the current COVID-19 pandemic, as evidenced by the signature of the Regional Comprehensive Economic Partnership (RCEP) agreement, the largest FTA in the world measured in terms of the size of population, on 15 November 2020 by ten ASEAN economies and five regional partners including China, Japan,

South Korea, Australia and New Zealand. About simultaneously, global value chains (GVCs) have sprung up and revolutionised the world's economic relations (Antrãs & Chor, 2021; Baldwin & Lopez-Gonzalez, 2013).

In this paper, we attempt to answer the following questions: What is the impact of FTA partnership on the bilateral GVC linkages? And how is this affected by the FTA partner's characteristics? To be more specific, we narrow down our scope and answer the question from the standpoint of a low-income country (see Section 4.2 for the definition of income group).

We first build a framework for how FTAs are formed based on GVCs to characterise a country's FTA-GVC relationship. Our GVC-based analysis is consistent with Markusen (1986) in studying North-North and North-South trade.[1] Since richer countries are more abundant in high-end factors (such as high-skilled labour) and therefore acquire higher value added in the GVC division of labour, when plotting each of the three quantities (i.e. per capita income level, abundance in high-end factors and the acquired value-added) with respect to the continuum of GVC segmented tasks, we have three isomorphic smiling curves, which can be used to characterise FTAs into vertical ones and horizontal ones. We then argue that for a low-end country like China, its FTAs with high-end partners will boost its GVC linkages with partners, as such FTAs are usually vertical FTAs that are in line with the GVC divisional of labour, while its FTAs with low-end partners will contribute little to its GVC linkages with partners, as such FTAs are usually horizontal FTAs in which partners are substituting instead of complementing each other.[2] The theoretical arguments are summarised by one hypothesis to be tested, with China being a representative low-end country in the GVCs. Specifically, we hypothesise that China will exhibit stronger GVC linkages with richer economies, and that the mutual GVC linkages between China and its FTA partners are more salient for more developed partners, and that such FTA partnerships are prone to engage in vertically integrated production.

We then use data from China to empirically evaluate our hypothesis. Specifically, we examine the impact of China's FTA partnership on its bilateral value chain linkages with a gravity-type two-way fixed effects (TWFE) model. We construct the GVC linkage indictors by the method of Leontief inverse and its recent generalisation (Miller & Blair, 2009; Wang et al., 2014) using the most recent Eora MIRO database. The FTA partnership and FTA type dummies are constructed by combining WTO RTA database and China's Ministry of Commerce's FTA database. The moderating variable, that is China's FTA partner's GVC position, is proxied by its per capita real income level and obtained from the World Bank and the UNCTADstat. The hypothesis is consistently validated in both the benchmark TWFE regressions and various robustness checks and additional analysis with product and sector level data.

There are a number of reasons why we believe that studying the problem using China is meaningful. First, China has been actively pursuing its FTA agenda, with 18 FTAs concluded (involving 26 individual economic partners), seven in negotiation (concerning 13 individual partners) and seven under consideration (covering seven individual partners). These FTA partners are quite heterogeneous in terms of development level which is presumed to associate with GVC location (See Table 1).[3] Second, as one of the largest trading countries in the world, China's rich-

[1]We thank James Markusen for pointing out this linkage.

[2]In this study, we assume that countries in the low-income group are producing homogeneous goods and do not have comparative advantage with each other. This rules out the possibility that some low-income countries do have comparative advantages in natural resources.

[3]See also Section 2 and Appendix S1 for a summary of China's FTA development.

TABLE 1 China's FTAs in force and under negotiation/consideration as of 2020

FTA in Force	Date	Potential FTA	Date
Hong Kong, China	Jan. 1, 2004	Under negotiation	
Macau, China	Jan. 1, 2004	GCC	Apr. 23–24, 2005
ASEAN[a]	Jul. 20, 2005	Norway	Sep. 18, 2008
Chile	Oct. 1, 2006	Japan-Korea[a]	Mar. 26–28, 2013
Pakistan	Jul. 1, 2007	Sri Lanka	Sep. 17–19, 2014
New Zealand	Oct. 1, 2008	Israel	Mar. 29, 2016
Singapore[a]	Jan. 1, 2009	Moldova	Dec. 28, 2017
Peru	Mar. 1, 2010	Panama	Jun. 12, 2018
Costa Rica	Aug. 1, 2011	Under consideration	
Iceland	Jul. 1, 2014	Colombia	
Switzerland	Jul. 1, 2014	Fiji	
Australia[a]	Dec. 20, 2015	Nepal	
South Korea[a]	Dec. 20, 2015	Papua New Guinea	
Maldives	Dec.7, 2017	Canada	
Georgia	Jan. 1, 2018	Bangladesh	
Mauritius	Oct. 17, 2019	Mongolia	
Cambodia[a]	Oct. 12, 2020		
RCEP	Nov. 15, 2020		

Note: Date refers to that in force or to the start of negotiation. GCC refers to Gulf Cooperation Council (i.e. Saudi Arabia, United Arab Emirates, Kuwait, Amen, Qatar and Bahrain), ASEAN refers to the Association of South East Asian Nations (i.e. Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam), and RCEP refers to Regional Comprehensive Economic Partnership.

[a]Denotes RCEP member.

ness, depth and diversity in trade and investment make it an example of low-income countries for studying the relationship between FTAs and GVCs. What is more, China is one of the limited few among low-income countries that has moved up from the lowest quartile to higher quartile range during the past more than two decades.[4] China is also among the few that have climbed up the value chain ladder over the same period (Baldwin & Lopez-Gonzalez, 2013; Kee & Tang, 2016). Have FTAs been beneficial, and if so, how, in improving China's value chain linkages with other economies? Learning from China's successful experience might prove helpful for other low-income countries, and those large ones in particular, in planning their FTAs.

This study contributes in the following ways. First, our research enriches the understanding of the relationship between FTAs and GVCs. The findings are helpful for re-examining a particular low-income country's FTA strategy. Though a number of recent studies have investigated a particular country such as China's FTA development (Antkiewicz & Whalley, 2005; Li et al., 2014), the paper provides different insights into global value chains. As international production becomes more disintegrated, this paper sheds light on how China's FTAs have formed, which is expected to be informative for similar developing countries.

[4]China moved up from the lowest quartile to a higher quartile range (above the 25th percentile) in 1993, and further jumped up to the mid-high-income group (above the 50th percentile) in 2014.

Second, following Markusen (2013), we proxy an economy's position along GVCs by the real per capita GDP. According to this criterion, the sample economies are divided into four groups. We also identify features of China's FTAs by decomposing its FTAs into different types. Some related literature (Antrãs & Chor, 2013, 2018; Antrãs et al., 2012; Fally, 2011; Miller & Temurshoev, 2017) attempts to construct indices of the upstreamness and downstreamness of GVCs. These indices are different from what we used in this paper as we are speaking in terms of the relative position on the transnational smiling curve.

Last but not least, the paper provides an empirical basis for answering the question of which partner(s) to choose in a country's GVC participation. UNCTAD (2013) raises this important question but does not answer it. It demonstrates the positive correlation between GVC participation and GDP growth. We push this relationship further. This paper shows that richer partners have larger shares in China's foreign content of value added. Consequently, richer partners play stronger roles in the positive correlation between China's GVC participation and GDP growth rate. To the extent that GVC linkages correlate positively with gains from trade (Timmer et al., 2014) and per capita GDP growth rate (UNCTAD, 2013) and hence presumably social welfare, our results provide hints for a low-income country in its FTA partner selection. Our idea can also find support from Wagner and Miranda (2016), who point out that the competitiveness of a country's value chain is affected by its neighbouring institutions, and from Kowalski and Gonzalez (2016) and Taglioni et al. (2016) who stress the importance of GVC integration for climbing up the GVC ladder and enhancing domestic performance, especially for developing economies.[5]

Our paper connects with two lines of research. The first is on the impact of FTAs. Plummer et al., 2010) argue that the FTA impact can be divided into the 'impact of what' and the 'impact on what'.[6] Theoretical analysis of the FTA impact can rest on partial equilibrium models or general equilibrium models. Nevertheless, much more research is needed on the empirical part of the problem.

When an FTA is in the negotiation stage, *ex-ante* analysis using trade indicators such as the RCA index or utilising CGE models is the typical choice. Koopman et al. (2013) constructed a GTAP model with GVCs that outperforms the standard GTAP models. Cai et al. (2015) used the dynamic GTAP model to evaluate the impact of TTIP on GVCs and the related spillover effects.

When an FTA is enforced, the actual impact is usually very different from the *ex-ante* projections. Now the assessment can be done using econometric methods such as the gravity model (Baier & Bergstrand, 2002, 2007; Egger et al., 2011; Trefler, 1993). The application of the gravity model needs to be modified to account for the GVC division of labour. Baldwin and Taglioni (2013) demonstrate that standard gravity models do not perform well when applied to bilateral trade flows. They modify the gravity equation to account for the GVCs. Other studies that have examined the impact of FTAs on GVCs include Lopez-Gonzalez (2012), Orefice and Rocha (2014), Kowalski et al. (2015) and Laget et al. (2020).

Second, our paper is related to the recent and growing literature on GVCs, ranging from theory to practice.[7] The theoretical models, such as those by Antrãs and Chor (2013, 2018), Costinot

[7]See Mattoo et al. (2013) for a recent summary of thoughts.

[5]A thorough welfare evaluation can be conducted through a general equilibrium analysis such as those carried out by Arkolakis et al. (2012), Caliendo and Parro (2015), Dixon et al. (2015). Though this study does not provide a theoretical model for welfare analysis, the empirical results lay the foundation for theoretical evaluations.

[6]See Baier and Bergstrand (2007, 2009), Egger et al. (2011), Narayanan et al. (2015) and Plummer et al. (2010) for more discussions.

et al. (2013), Dixit and Grossman (1982), Feenstra and Hanson (1999), Gereffi (1999), Grossman and Rossi-Hansberg (2008), and Grossman and Rossi-Hansberg (2012), tackle the problem from the trade in tasks perspective. Empirical models such as the GVC measurement focus on the decomposition of gross trade into value-added trade components, the quantification of backward and forward linkages, and the location of GVCs.[8]

The rest of the study proceeds as follows. Section 2 briefly introduces China's FTA history. Section 3 starts with theoretical argument and ends with the hypothesis and the econometric model. Section 4 discusses the data and variables. Empirical results are presented and discussed in Section 5, and Section 6 concludes.

2 | CHINA'S FTA DEVELOPMENT

In 2001, China became a member of the WTO. This is a milestone in China's integration into the world economy (Lardy, 2002). Since its accession to the WTO, China has been actively engaged in pursuing FTAs (Li et al., 2014). Table 1 displays China's FTAs in force, under negotiation and in planning.[9]

Most of China's FTA partners are in Asia. The CEPA (Closer Economic Partnership Arrangement) is China's first FTA with Hong Kong, China and Macau, China signed on 29 June 2003. The CEPA has been updated several times since its implementation. The ACFTA (ASEAN-China Free Trade Area) was ever China's largest FTA in terms of population, and the third largest in terms of nominal GDP, before the RCEP was signed in 2020. The initial agreement was signed in November 2002. The agreement was updated in November 2015. The China-Pakistan FTA was signed in November 2006. Its updated version, the Agreement on Trade in Service, was signed in February 2009. The China–Singapore Free Trade Agreement (CSFTA) was signed in October 2008. The China-South Korea FTA was signed in June 2015. China has also signed bilateral FTAs with three small Asian countries, that is Maldives (in December 2017), Georgia (in January 2018) and Cambodia (in October 2020) respectively.

China has three FTAs with Latin and South American countries, namely Chile, Peru and Costa Rica, signed in November 2005, April 2009 and April 2010 respectively. In Oceania, China has two FTA partners. The China-New Zealand FTA was signed in April 2008. The China-Australia FTA was signed in June 2015. In Europe, China's has two FTA partners. The China-Iceland FTA was signed in April 2013, while China's FTA with Switzerland was signed in July 2013. In Africa, Mauritius is the first country that signed a FTA with China in October 2019.

The RCEP is now China's largest FTA in terms of population, GDP, trade and investment. It is a typically vertical mega FTA with members of different income levels and GVC locations, and thus viewed as a significant step towards Asian-Pacific economic integration. The future development of this newly formed FTA can draw implications from the experience of other FTAs examined in this study.

[8]See, for example Antrãs et al. (2012), Antrãs and Chor (2013,2018), Baldwin and Lopez-Gonzalez (2013), Baldwin and Robert-Nicoud (2014), Chor et al. (2021), Daudin et al. (2011), Hummels et al. (2001), Johnson and Noguera (2012), Koopman et al. (2014), Lau et al. (2007), Stehrer et al. (2012) and Wang et al. (2014).

[9]The updated information comes from various research articles, reports and the relevant official websites such as http://rtais.wto.org/ and http://fta.mofcom.gov.cn/. See also the Appendix S1 for more detailed description of China's FTAs.

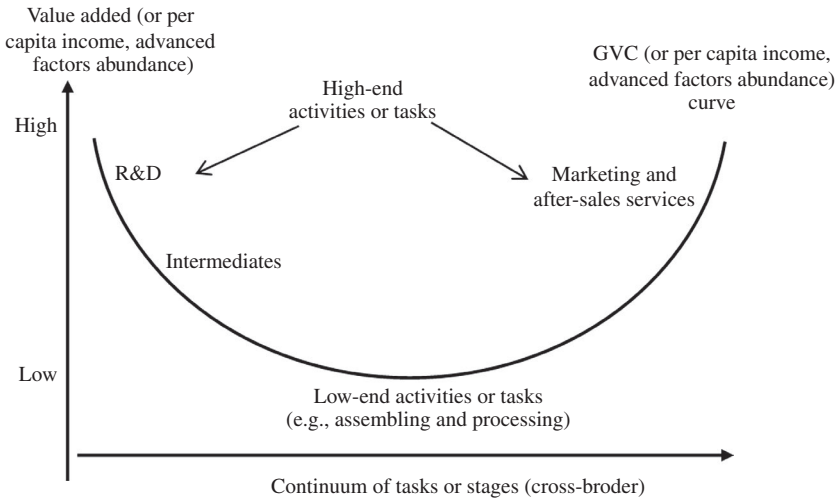

FIGURE 1 Global Value Chain (GVC) and GVC-based FTA Formation Mechanism. Advanced factors not only refer to the usual high-skilled human capital but also include factors regarding management, institution, system and mechanism that are conducive to climbing up and maintaining the higher ends of GVCs. GVC-based FTA can be constructed from both national and sectoral perspectives. Source: Authors' plot

3 | THEORETICAL HYPOTHESIS AND EMPIRICAL MODEL

Traditionally, various forms of regional economic integration can be roughly grouped as vertical and horizontal by partners' development levels. Vertical integration happens with partners of different economic development levels, while horizontal integration happens with partners of identical or similar levels. A similar idea can be borrowed to classify FTAs from the point of view of GVCs.

According to the definition of Baldwin and Venables (2013), GVCs can be sequential (*snake*) or horizontal (*spider*), corresponding to vertical and horizontal fragmentation respectively.[10] Our goal is to link GVC (or fragmentation) patterns to the formation of FTAs, as both of them involve different economies with different factor endowments and income levels. To understand the intrinsic logic, we rely on Figure 1 for a brief analysis. The horizontal axis of Figure 1 portrays a continuum of GVC stages or tasks, such as research and development (R&D), intermediates, assembling and processing, and marketing and after-sales services. The vertical axis of Figure 1 represents the value-added stages or tasks.

The GVC curve in Figure 1 can be viewed as a per capita income curve. In other words, the high-end level of tasks is approximately positively correlated with the income level.[11] Furthermore, the GVC curve also reflects the relative abundance of different factors along the GVC. Higher-end or more advanced factors correspond to higher value-added, and a richer country is usually abundant in higher-end factors. Therefore, a country's relative abundance of higher-end or more advanced factors decides its position along the GVC and its income level.

[10]Indeed, most GVCs are complex mixtures of the two, yet the two are fundamental building blocks of any GVC network.

[11]Markusen (2013) pointed out the important role of per capita income in international trade.

With the three curves approximately integrated as a single curve shown in Figure 1, we group FTAs into two types. One is characterised by vertical GVCs with member economies of different income levels locating at different GVC positions (henceforth vertical FTA) and the other by horizontal GVCs with member economies of similar income levels at similar GVC locations (henceforth horizontal FTA). Moreover, there are two extreme types for the latter category: the higher-end horizontal FTA with economies all at the high end of GVCs and a high-income level, and the low-end horizontal FTA with economies all at the low end and a low-income level.[12]

We now consider the effect of FTA partnership on GVC linkages. Such a relationship is apparently contingent on features of FTA partners. To be specific, we look at the problem from the perspective of a low-income country such as China. Our data sample starts from 1990 and ends at 2015. In 1990, China's real per capita GDP (in 2010 USD) was $705 and in the lowest quartile among 163 economies. In 2015, China's real per capita GDP (in 2010 USD) was $6344 and between the median and highest quartile (i.e. between the 50th and 75th percentile) among 186 economies. So, China had moved up during the period. Nevertheless, it was still at the lower end at least before 2013.[13]

By definition, bilateral GVC linkages increase when both parties get more involved in each other's value chains. For a low-end country like China, forming FTA(s) with higher-end partner(s) usually boost GVC linkages, while forming FTA(s) with low-end economies contributes little to value chain growth. The reason is simple. An FTA with a high-end partner is formed on the basis of vertical GVCs and is relatively more liberalised and market motivated thanks to the exemplary role of the high-end partner. However, at the lower end with a horizontal FTA, all partners are lagged in terms of economic development with limited domestic demand. These countries also have restricted markets. Therefore, it is highly likely that government intervention dominates their FTA framework. Moreover, within such FTAs, partners have a similar or even identical industrial and product composition, which means that the products developed by these partners are quite homogeneous. Consequently, these lower-end partners are mutually substitutable rather than complementary to each other and can hardly penetrate each other's value chains. These implications are in line with Markusen (1986), who investigated the pattern of North-North and North-South trade using a general equilibrium framework.

Based on the above discussion, we formulate one hypothesis, with China being a representative low-income country:

Hypothesis 1 *For an arbitrary economy in the open world, whether it be China's FTA partner or not, the higher the income level it has, the stronger the GVC linkages it has with China. Among China's FTA partner economies, the higher the income level an individual economy has, the stronger the mutual GVC dependence it has with China, and in terms of GVC labour division, such an FTA is vertical.*

We can test the above hypothesis by using China's FTA experience. Specifically, we can test with historical data whether and how China's FTA partnerships influence the bilateral value chain linkage between China and its partners. We follow the literature (de Chaisemartin &

[12]Indeed, a continuum of a horizontal FTA can be identified based on a continuum of tasks and stages along the GVC.

[13]The years 1992 and 2013 are two turning points when China jumped from the lowest-income group to higher-income groups. In 2013, China's real per capita GDP (in 2010 USD) was $5588 and between the lowest and median quartile among 186 economies.

D'Haultfœuille, 2020, 2021) to adopt a gravity-type two-way fixed effects model to measure the effect of FTA partnership on GVC linkages:

$$GVC-CHN_{it}=\beta_1 Y_{it}+\beta_2 FTA-CHN_{it}+\beta_3 Y_{it}*FTA-CHN_{it}+\alpha_i+\lambda_t+\varepsilon_{it}, \quad (1)$$

where $GVC-CHN_{it}$ is the bilateral GVC linkage between China and its (FTA or non-FTA) partner i at year t; Y_{it} is the log of the partner i's real per capita GDP at year t; $FTA-CHN_{it}$ is a dummy for China's FTA partnership (one for being the FTA partner of China and zero otherwise); $Y_{it}*FTA-CHN_{it}$ is an interaction between partner i's income level and the FTA partnership dummy, which is used to identify the moderating effect of the partner's income level; α_i and λ_t represent country and year fixed effects, respectively[14]; and ε_{it} is the stochastic disturbance term.

4 | DATA AND VARIABLES

In this section, we first introduce the measurement of GVC linkages relying on inter-country input–output tables. Then, we discuss country grouping based on income levels and global FTA dataset. In the robustness checks of Section 5, we examine other variables including Chinese bilateral FDI and tariffs, partner's GDP, geographical distance between China and its partner.

4.1 | The GVC linkages

To quantify the dependent variable in Equation (1), that is China's GVC linkage with its partners, we focus on two perspectives: backward linkage and forward linkage.

The computation method follows Leontief (1936), Miller and Blair (2009) and Wang et al. (2014). Specifically, the total value added induced by one unit of output is calculated as the sum of direct and indirect value added generated from the production process of one unit of output:

$$\begin{aligned} V+VA+VAA+VAAA+\ldots &= V\left(I+A+A^2+A^3+\ldots\right) \\ &= V(I-A)^{-1}=VL \end{aligned} \quad (2)$$

where V is the direct value-added coefficient vector; A is the intermediate input coefficient matrix; and $L=(I-A)^{-1}$ is the Leontief inverse matrix. VL is the total value-added coefficient matrix (or the total value-added multiplier).

[14]As Fuchs and Klann (2013) discussed, the effect of bilateral distance and other time-invariant factors such as being landlocked or contiguous can be captured by the partner country fixed effects, but the inclusion of a full set of country-by-year effect is not feasible in our model as we estimate bilateral GVC linkage between a specified country (China) and its partners.

TABLE 2 Descriptive statistics on the GVC linkages between China and its partners (1990–2015)

	Forward linkage				Backward linkage			
	C_dep		*P_dep*		*C_dep*		*P_dep*	
Product/sector	**Mean (%)**	***N***	**Mean (%)**	***N***	**Mean (%)**	***N***	**Mean (%)**	***N***
Aggregate	1.019	4842	0.082	4862	0.065	4862	0.904	4862
Final (for export)	1.236	4842	0.107	4862	0.073	4862	1.145	4862
Intermediate (for export)	0.636	4842	0.125	4862	0.072	4862	1.000	4862
Final (for home)	0.672	4842	0.059	4862	0.055	4862	0.705	4862
Intermediate (for home)	1.533	4842	0.038	4862	0.060	4862	0.765	4862
Agriculture	1.486	4836	0.027	4862	0.023	4862	0.550	4825
Fishing	0.590	4813	0.025	4862	0.027	4862	0.927	4813
Mining	3.208	4831	0.110	4862	0.041	4862	0.807	4095
Food	0.436	4713	0.030	4862	0.034	4862	0.852	4862
Textiles	1.277	4839	0.111	4862	0.062	4862	1.887	4835
Wood and Paper	1.163	4842	0.079	4862	0.068	4862	0.960	4807
Petroleum	1.473	4842	0.090	4862	0.071	4862	1.120	4781
Metal Products	2.238	4842	0.104	4862	0.077	4862	1.301	4615
Electrical and Machinery	1.461	4840	0.101	4862	0.116	4862	1.523	4797
Transport Equipment	0.646	4834	0.048	4862	0.086	4862	1.597	4757
Other Manufacturing	0.636	4832	0.107	4862	0.068	4862	1.448	4822
Recycling	1.568	4795	0.115	4862	0.002	4862	1.244	4636
Electricity	0.885	4773	0.065	4862	0.045	4862	0.543	4862
Construction	0.222	4825	0.004	4862	0.074	4862	0.871	4862
Maintenance and Repair	0.776	4812	0.081	4862	0.033	4862	0.747	4862
Wholesale Trade	0.603	4833	0.081	4862	0.033	4862	0.639	4862
Retail Trade	0.349	4790	0.081	4862	0.033	4862	0.510	4862

(Continues)

TABLE 2 (Continued)

	Forward linkage				Backward linkage			
	C_dep		*P_dep*		*C_dep*		*P_dep*	
Product/sector	**Mean (%)**	***N***	**Mean (%)**	***N***	**Mean (%)**	***N***	**Mean (%)**	***N***
Hotels and Restaurants	0.313	4838	0.037	4862	0.029	4862	0.642	4862
Transport	0.910	4820	0.078	4862	0.043	4862	0.798	4862
Post and Telecom	0.469	4842	0.060	4862	0.041	4862	0.551	4862
Finance	0.509	4842	0.063	4862	0.035	4862	0.395	4862
Public Administration	0.095	4840	0.000	4862	0.031	4862	0.634	4862
Education, Health	0.153	4838	0.022	4862	0.040	4862	0.490	4862
Private Households	0.747	4803	0.097	4862	0.047	4862	0.813	4862
Others	0.722	4710	0.000	4862	0.031	4862	0.768	4836

Note: The products are classified into four kinds, that is final and intermediate both for export and for domestic (home) use. The mean value is in terms of percentage (%). The number of observations is equal to the product of the number of China's partners (the maximum is 187) and that of years (the maximum is 26, i.e. from 1990 to 2015).

We decompose the country/sector level value added as follows. Suppose, we have C countries and N sectors:

$$\begin{aligned}\widehat{V}L\widehat{Y} &= \begin{bmatrix} V^1 & 0 & 0 & 0 \\ 0 & V^2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & V^C \end{bmatrix}\begin{bmatrix} L^{11} & L^{12} & \dots & L^{1C} \\ L^{21} & L^{22} & \dots & L^{2C} \\ \vdots & \vdots & \ddots & \vdots \\ L^{C1} & L^{C2} & \dots & L^{CC} \end{bmatrix}\begin{bmatrix} Y^1 & 0 & 0 & 0 \\ 0 & Y^2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & Y^C \end{bmatrix} \\ &= \begin{bmatrix} V^1L^{11}Y^1 & V^1L^{12}Y^2 & \dots & V^1L^{1C}Y^C \\ V^2L^{21}Y^1 & V^2L^{22}Y^2 & \dots & V^2L^{2C}Y^C \\ \vdots & \vdots & \ddots & \vdots \\ V^CL^{C1}Y^1 & V^CL^{C2}Y^2 & \dots & V^CL^{CC}Y^C \end{bmatrix}\end{aligned} \tag{3}$$

where $\widehat{V}$ is the '$(C \times N) \times (C \times N)$' diagonal matrix of direct value-added coefficients; and $\widehat{Y}$ is the '$(C \times N) \times (C \times N)$' matrix of each country's/sector's production submatrix arranged along the diagonal. The matrix of final equation of Equation (3) characterises the sector and country sources of value added in each country's production. According to Wang et al. (2014), the sum of the $\widehat{V}L\widehat{Y}$ across columns accounts for how each country's domestic value added that originated in a particular sector is used by the sector itself and all its downstream countries/sectors, while the sum of the $\widehat{V}L\widehat{Y}$ across the rows represents all upstream countries'/sectors' value-added contributions to a country's/sector's production. The former values trace forward linkages across all downstream countries/sectors, while the latter items trace backward linkages across upstream countries/sectors.

Now let us focus on China. The dependence of China on an upstream partner (denoted by *C_dep*) and the dependence of a partner on China at the upstream of GVC (denoted by *P_dep*) are specified by forward and backward linkages respectively. The former dependence is calculated as the percentage (%) of an upstream partner i's value added in China's total value added, that is $C\_dep = \left(V^{i-CHN} / \sum_{i \neq CHN}^{C} V^{i-CHN} + V^{CHN-CHN}\right) \times 100\backslash\%$. The latter is calculated as the share of China's value added in a partner i's total value added, that is $P\_dep = \left(V^{CHN-i} / \sum_{j \neq i}^{C} V^{j-i} + V^{i-i}\right) \times 100\backslash\%$.

We use the Eora MRIO database to calculate the values of $GVC - CHN_{it}$, as represented by *C_dep* and *P_dep*. There are 188 economies, 26 sectors and 26 years in the Eora MRIO database (Lenzen et al., 2013), the broadest country coverage we have among the existing ICIO dataset. Descriptive statistics on $GVC - CHN_{it}$ are displayed in Table 2. Asymmetry of the bilateral forward and backward linkages between China and its partners can be easily detected. China's dependence is stronger than its partners' dependence if measured by forward linkage, but is weaker than its partners' dependence if measured by backward linkage. For example, in 2015, all the ratios of *P_dep* to *C_dep* in terms of backward linkage are larger than one except for Myanmar, and all the ratios of *P_dep* to *C_dep* in terms of forward linkage are smaller than one except for the United States. In addition, products and sectors are heterogeneous in terms of GVC linkages. Exported products on average exhibit higher backward linkages than those for domestic use, while the patterns are mixed in terms of forward linkage. Among the sectors, mining has the highest average *C_dep* (3.208%), and recycling has the highest average *P_dep* (0.115%) in terms of forward linkage. Electrical and machinery sector has the highest average *C_dep* (0.116%), and textiles and wearing apparel sector has the highest average *P_dep* (1.887%) in terms of backward linkage.

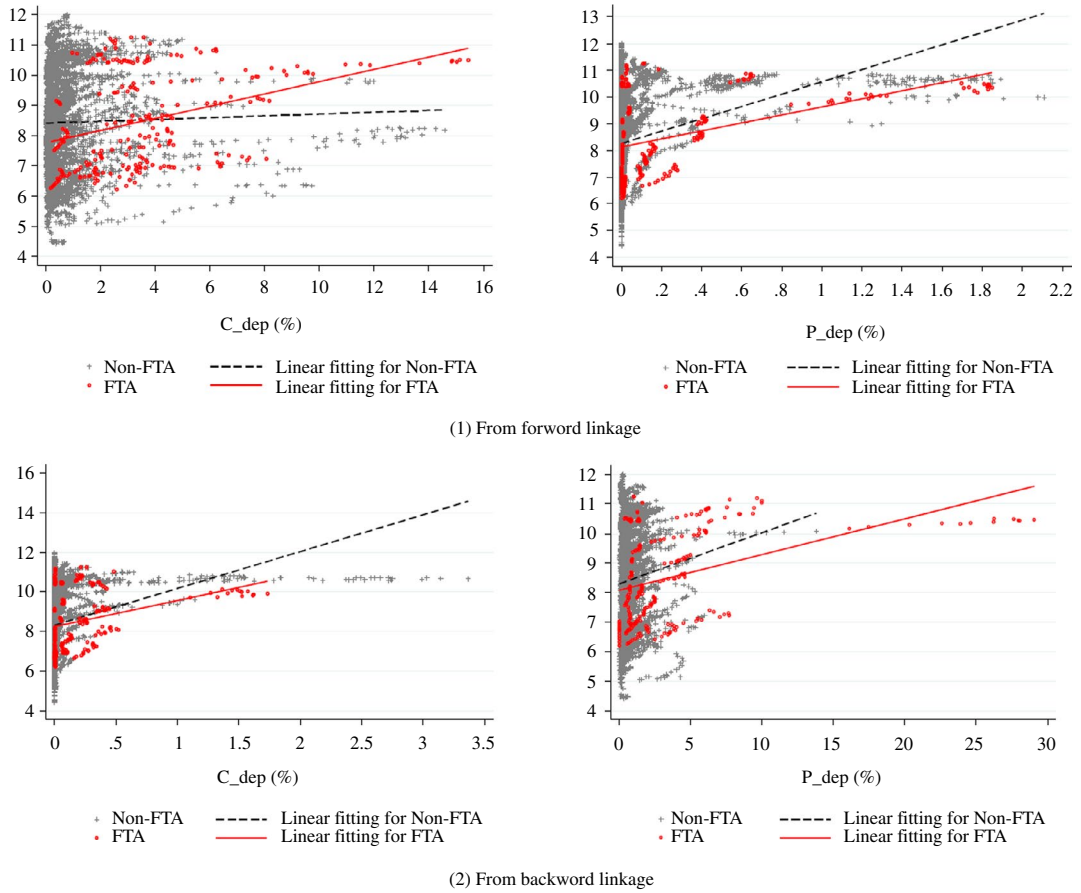

FIGURE 2 Correlation between China's Bilateral VA Linkages and Its Actual and Potential Partners' Per Capita GDP. The vertical axis represents partner's per capita GDP (in logs). China's partners are divided into FTA partners and non-FTA partners. Source: Authors' plot

4.2 | Income level and country grouping

We group countries by their income levels, that is real per capita GDP, using data from the World Bank and the UNCTADstat.

The income variable is used in two versions. First, it is used as a continuous variable in the form of the logarithm of real per capita GDP. Second, it is used as a discrete variable in the form of the categories of countries: Group 1 is the group with real per capita GDP below the 25th percentile and represents the low-end group; Group 2 is the group with real per capita GDP between the 25th percentile and 50th percentile and represents the low-mid-end group; Group 3 is the group with real per capita GDP between the 50th percentile and the 75th percentile and represents the mid-high-end group; and Group 4 is the group with real per capita GDP above the 75th percentile and represents the high-end group. Group 1 is used as the benchmark group, and Y_H (1 for high-end group, 0 for others), Y_{MH} (1 for mid-high-end group, 0 for others) and Y_{LM} (1 for low-mid-end group, 0 for others) are dummies for the other three groups.

Figure 2 presents descriptive evidence showing a positive correlation between China's bilateral GVC linkages and its actual and potential FTA partner economies' income. Moreover, to

TABLE 3 China's FTA partnership and GVC linkages: Baseline

	Forward linkage				Backward linkage			
	C_dep		*P_dep*		*C_dep*		*P_dep*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Y	−0.090	−0.115	0.001	0.001	0.004	0.006	0.199	0.152
	(0.270)	(0.266)	(0.014)	(0.013)	(0.012)	(0.011)	(0.137)	(0.133)
FTA	−2.737	−3.176	−0.129	−0.133	−0.105	−0.096	−5.525	−5.925
	(2.180)	(2.286)	(0.098)	(0.103)	(0.137)	(0.139)	(3.655)	(3.838)
*Y*FTA*	0.510*	0.567*	0.021*	0.021	0.020	0.019	0.813*	0.873*
	(0.282)	(0.299)	(0.013)	(0.014)	(0.018)	(0.019)	(0.490)	(0.517)
$adj.R^2$	0.439	0.444	0.056	0.062	0.098	0.098	0.420	0.430
p	.000	.000	.000	.004	.002	.002	.000	.000
N	4781	4597	4801	4616	4801	4616	4801	4616

Note: The independent variables in specifications (2), (4), (6) and (8) are in one-year lags. All regressions with economy and year fixed effects. Constants are omitted to save space. Standard errors in brackets are adjusted for clustering across partner economies. *FTA* is a dummy for China's FTA in force at present (1 represents the economy being China's FTA partner, otherwise 0). *Y* is for partner's real per capita GDP in logarithm.

*Significant at 10%, **Significant at 5%, ***Significant at 1%.

TABLE 4 China's FTA partnership and GVC linkages: Baseline (China's partners divided into four groups)

	Forward linkage				Backward linkage			
	C_dep		*P_dep*		*C_dep*		*P_dep*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Y_H	0.617**	0.532*	0.009	0.001	0.028	0.024	0.412**	0.372*
	(0.302)	(0.296)	(0.034)	(0.037)	(0.032)	(0.030)	(0.195)	(0.227)
Y_MH	0.115	0.092	−0.041	−0.041	−0.012	−0.012	−0.002	−0.038
	(0.161)	(0.160)	(0.029)	(0.034)	(0.010)	(0.009)	(0.091)	(0.091)
Y_LM	0.015	0.003	−0.027	−0.020	−0.005	−0.005	−0.001	−0.052
	(0.102)	(0.102)	(0.019)	(0.017)	(0.005)	(0.005)	(0.058)	(0.059)
FTA	0.818*	0.745*	0.016	0.019	0.009	0.013	0.590	0.605
	(0.427)	(0.415)	(0.015)	(0.018)	(0.018)	(0.020)	(0.468)	(0.473)
*Y_H*FTA*	1.978*	2.184*	0.076*	0.073	0.056	0.046	3.106	3.361
	(1.119)	(1.186)	(0.045)	(0.047)	(0.050)	(0.051)	(2.020)	(2.151)
*Y_MH*FTA*	0.917	1.135	0.044	0.048	0.141*	0.138*	0.196	0.278
	(0.836)	(0.810)	(0.036)	(0.042)	(0.082)	(0.081)	(0.649)	(0.669)
*Y_LM*FTA*	0.316	0.379	0.023	0.011	0.077**	0.070*	−0.152	−0.197
	(0.585)	(0.608)	(0.022)	(0.023)	(0.039)	(0.041)	(0.590)	(0.612)
adj. R^2	0.444	0.447	0.047	0.050	0.111	0.112	0.447	0.458
p	.000	.000	.126	.042	.001	.000	.000	.000
N	4842	4656	4862	4675	4862	4675	4862	4675

Note: The independent variables in specifications (2), (4), (6) and (8) are in one-year lags. All regressions with economy and year fixed effects. Constants are omitted to save space. Standard errors in brackets are adjusted for clustering across partner economies. *FTA* is a dummy for China's FTA in force at present (1 represents the economy being China's FTA partner, otherwise 0). *Y_H* = 1 for high-end group, 0 for others; *Y_MH* = 1 for mid-high-end group, 0 for others; *Y_LM* = 1 for low-mid-end group, 0 for others.

*Significant at 10%, **Significant at 5%, ***Significant at 1%.

check the robustness of per capital GDP as a proxy of an economy's position along the GVCs, we use the WIOD world input–output tables (Timmer et al., 2015) and follow the implication of Figure 1 to establish a GVC position index, which is measured by the share of value added by high-skilled labour in total domestic value added. The result confirms that the GVC position index is highly positively correlated with per capita GDP (see Figure A4 in the Appendix S1).[15]

4.3 | FTA partnership and types

China's FTA partnership dummy is $FTA - CHN_{it}$, with one being the FTA partner of China and zero otherwise. This dummy is constructed by combining the data from the WTO RTA database (http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx) and China's Ministry of Commerce (http://fta.mofcom.gov.cn/).

We match the per capita GDP dataset and the FTA dataset, and obtain 200 perfectly matched economies. Based on this, we can identify different types of FTAs (e.g. vertical or horizontal FTA). We then merge the above three datasets together by the economy name, and 180 economies are perfectly matched. All existing and potential FTA partners of China are in this group of matched economies. As discussed in Section 2, China is now implementing 18 FTAs involving 26 individual economies, and negotiating or considering other FTAs (see Table 1).[16]

5 | RESULTS

5.1 | Main results

The parameters are estimated using panel fixed effects OLS regressions. The standard errors are adjusted for clustering across partner economies, as a modified Wald test suggests groupwise heteroskedasticity. Tables 3 and 4 report the empirical results for aggregate-level data from forward and backward perspectives. Each column represents a model specification.

The first four models in Table 3 tell the story in terms of forward linkage about the dependence between China and its FTA partners. All the models show a mixed and statistically insignificant correlation between China's bilateral GVC dependence and the partners' income level. However, we find significantly positive coefficients (0.510, 0.567 and 0.021) on the interaction term of FTA dummy and income level in models (1), (2) and (3), but insignificantly negative coefficients (−2.737, −3.176 and −0.129) on the FTA dummy and insignificant mixed coefficients (−0.090, −0.115 and 0.001) on the income level. Arguably, the latter effect is already captured by the former. Therefore, although overall

[15]The reason for using the WIOD dataset (http://www.wiod.org/) for a robustness check is that it contains information about VA by different types of labour (high-skilled, medium-skilled and low-skilled) (from 1995 to 2010 for 38 countries), but the above Eora MRIO database has no such information. We use the value-added share by high-skilled labour rather than the conventional export sophistication (Jarreau and Poncet, 2012) for a robustness check, mainly because the former considers the VA decomposition and thus is consistent with the GVC context, while the latter is in terms of gross trade rather than value-added trade. However, the WIOD sample has a shorter time period and smaller country coverage than the Eora data used throughout the paper. This could be a caveat for the results. Nevertheless, the WIOD sample countries account for over 80% of world total GDP.

[16]Figure A5 in the Appendix S1 displays the changes in bilateral gross trade and GVC linkages between China and some of its key partners before and after the agreement. More detailed information can be available upon request.

an FTA partnership is expected to help enhance bilateral GVC linkages, this happens only if the partner economy is rich enough. This indicates that the partner's development level does matter in terms of the impact of FTA on China's bilateral GVC linkages. Laget et al. (2020) also find the income level matters for GVC integration, while their WIOD sample is much smaller than ours.

Similar results can be found in Equations (2) and (4) with all the independent variables being in one-year lag.

The situation in terms of backward linkage is presented in the last four models in Table 3. The positive albeit insignificant correlation between GVC dependence and income level appears again. It shows positive coefficients (0.020 and 0.813) on the interaction term of FTA dummy and income level in models (5) and (7), but the former is statistically insignificant, while the latter significant.

The basic results remain the same when all the explanatory variables are used in one-year lag for specifications (6) and (8).

Comparing the coefficients of various models, we find asymmetric impacts of the interaction term of FTA dummy and income level on the bilateral mutual value chains linkage. For the forward linkage, the impacts on China's dependence outweigh those on partners' dependence, while the reverse is true for the backward linkage. As the forward linkage reflects the factor content of trade, a stronger dependence of China implies China's deeper linkage to its partner through exporting. In terms of backward linkage, a larger partner's dependence implies a higher share of China's value added in its total value added. Therefore, the asymmetric impacts from two perspectives actually tell the same story.

Moreover, to compare with the existing literature on the impact of FTAs on trade in gross terms rather than in value-added terms, we rely on the popular UC-Davis goods trade database to make regressions from import and export aspects in the same period of 1990–2015.[17] For import, we denote *C_dep* as the share of China's import from a partner in China's total import, and *P_dep* as the share of a partner's import from China in the partner's total import. For export, we denote *C_dep* as the share of China's export to a partner in China's total export, and *P_dep* as the share of a partner's export to China in the partner's total export. Appendix S1: Table A1 reports the final results. It can be seen that the correlation between a partner's income level and the mutual trade dependence is positive but insignificant, which is similar to Table 3. But the impacts of the interaction term of the FTA dummy and income level on China's bilateral trade linkages are largely different from the results in Table 3. The coefficients of all models are statistically insignificant or significantly negative. This implies that for China the impact of an FTA on trade dependence is not significantly positive and does not increase as the partner gets richer.

Therefore, the comparison signifies the importance of the GVC linkage perspective in looking at the impact of FTA formation, as the gross trade connections may conceal the actual but not directly observable GVC linkages among countries.

Table 4 reports results where the income level is expressed in dummies. The situation is largely similar to the continuous usage.

The inclusion of FTA interaction terms reveals that the choice of partners matters for FTAs' promoting effect on GVC linkage. Alternatively, the coefficients on the FTA interaction term reflect the differences in impact of two scenarios: an FTA between China and the current group (high-end, or mid-high-end or low-mid-end group) and an FTA between China and the benchmark group (i.e. low-end group). In the case of forward linkage (see the first four models in Table 4), such an impact on the mutual dependence between China and its partner is statistically significantly positive at the 10% level, if the partner falls into the high-end group. For the backward

[17]The data are obtained from https://cid.econ.ucdavis.edu/.

TABLE 5 China's FTA partnership and GVC linkages: IV Strategy

	Forward linkage		Backward linkage	
	C_dep	*P_dep*	*C_dep*	*P_dep*
	(1)	(2)	(3)	(4)
Y	−0.092	0.000	0.002	0.173
	(0.283)	(0.012)	(0.010)	(0.140)
FTA	−3.472	−0.145	−0.101	−6.487
	(2.495)	(0.112)	(0.151)	(4.172)
*Y*FTA*	0.613*	0.023	0.020	0.948*
	(0.324)	(0.015)	(0.020)	(0.557)
S-W *F* test (*p*)	.000	.000	.000	.000
Endogeneity test	6.055	4.172	3.131	4.273
	(0.048)	(0.124)	(0.209)	(0.118)
R^2	0.442	0.062	0.102	0.418
N	4595	4614	4614	4614

Note: All regressions with economy and year fixed effects. Constants are omitted to save space. Standard errors in brackets are adjusted for clustering across partner economies. *FTA* is a dummy for China's FTA in force at present (1 represents the economy being China's FTA partner, otherwise 0). Y is for partner's real per capita GDP in logarithm.

*Significant at 10%, **Significant at 5%, ***Significant at 1%.

linkage (see the last four models in Table 4), the interaction effects of FTAs are always positive, and in particular statistically significant at the conventional levels for the case where China chooses to form FTAs with the mid-high-end economies, if China does not partner with low-end economies.

Once again, for a comparison with GVC linkages, we report the regression results on China's FTA partnerships and the gross trade linkages in Appendix S1: Table A2. It is shown that the coefficients on the three FTA interaction terms are very mixed except for models (1), (2), (7) and (8). These four models reveal that forming an FTA with a higher-income economy will strengthen the partner' trade dependence on China.

In summary, forming FTAs with richer economies, those in Groups 3 and 4 in particular, is mutually dependence enhancing. It increases the share of an upstream partner' value added in China's total value added and thus China's dependence on its partner, and also raises the share of China's value added in the partner's total value added and thus dependence on China. The results from both forward and backward linkages confirm the findings in Table 3.

5.2 | Endogeneity issue

There might be an endogeneity issue in Equation (1). This paper uses income and its interaction with FTA partnerships to explain the variation in GVC linkages[18], the key variable FTA dummy,

[18]The literature argues that the prevalence of zero trade flows in gravity models may cause biased estimates. Our index of GVC linkage is similar to that of trade flows. In our sample, however, this issue seems to be negligible since the number of zero GVC linkages (only for China's dependence in terms of backward linakge) is very small (for China's backward dependence, 20 zeros of 4862 observations in the aggregate analysis, and 520 zeros of 126412 observations in the sectoral analysis).

TABLE 6 China's FTA partnership and GVC linkages: IV Strategy (China's partners divided into four groups)

	Forward linkage		Backward linkage	
	C_dep	*P_dep*	*C_dep*	*P_dep*
	(1)	(2)	(3)	(4)
Y_H	0.625**	0.004	0.029	0.226
	(0.288)	(0.037)	(0.031)	(0.207)
Y_MH	0.189	−0.043	−0.012	0.021
	(0.165)	(0.035)	(0.010)	(0.092)
Y_LM	0.067	−0.021	−0.004	0.025
	(0.101)	(0.018)	(0.005)	(0.061)
FTA	0.817*	0.022	0.013	0.678
	(0.449)	(0.019)	(0.020)	(0.513)
*Y_H*FTA*	2.346*	0.078	0.051	3.616
	(1.281)	(0.050)	(0.055)	(2.322)
*Y_MH*FTA*	1.238	0.050	0.156*	0.209
	(0.926)	(0.046)	(0.095)	(0.702)
*Y_LM*FTA*	0.372	0.011	0.073	−0.242
	(0.667)	(0.026)	(0.045)	(0.670)
S-W *F* test (*p*)	.000	.000	.000	.000
Endogeneity test	7.431	5.49	4.501	8.795
	(0.115)	(0.241)	(0.342)	(0.066)
R^2	0.447	0.054	0.115	0.443
N	4656	4675	4675	4675

Note: All regressions with economy and year fixed effects. Constants are omitted to save space. Standard errors in brackets are adjusted for clustering across partner economies. *FTA* is a dummy for China's FTA in force at present (1 represents the economy being China's FTA partner, otherwise 0). *Y_H* = 1 for high-end group, 0 for others; *Y_MH* = 1 for mid-high-end group, 0 for others; *Y_LM* = 1 for low-mid-end group, 0 for others.

*Significant at 10%, **Significant at 5%, ***Significant at 1%.

and the interaction term might be influenced by these GVC linkages. Researchers have already drawn attention to, and attempted to address, the endogeneity issue in estimating the impact of FTAs on trade volumes (Baier & Bergstrand, 2002, 2007; Egger et al., 2011; Trefler, 1993). In this study, the situation is not the same. The endogeneity between income and GVC linkage is likely to be a minor issue. It seems natural that forming an FTA partnership will improve GVC dependence. However, it is unclear whether GVC linkage leads to FTA construction. In reality, the decision as to whether to sign an FTA is complicated, and many factors need to be considered. For example, China has very strong GVC linkages with Japan, the United States and Germany, but has not signed an FTA with any of them. To address the endogeneity of the FTAs, we adopt two approaches, that is the instrumental variable approach and the propensity score matching approach.

TABLE 7 China's FTA partnership and GVC linkages: Based on matched sample

	Forward linkage				Backward linkage			
	C_dep		*P_dep*		*C_dep*		*P_dep*	
	(1)	(2)	(3)	(4)	(5)	(7)	(6)	(8)
Y	0.006	0.063	0.012	0.023*	0.019	0.026	0.378*	0.158
	(0.277)	(0.250)	(0.018)	(0.013)	(0.015)	(0.019)	(0.222)	(0.299)
FTA	−1.836	−1.966	−0.148*	−0.090**	−0.082	0.026	−3.899	−2.754
	(1.904)	(1.663)	(0.085)	(0.044)	(0.093)	(0.049)	(3.349)	(2.975)
*Y*FTA*	0.361****	0.336****	0.022*	0.012**	0.015	−0.001	0.564	0.404
	(0.243)	(0.210)	(0.011)	(0.006)	(0.012)	(0.006)	(0.434)	(0.380)
$adj.R^2$	0.421	0.432	0.046	0.030	0.071	0.021	0.332	0.281
p	.000	.000	.002	.002	.000	.002	.000	.000
N	2563	2226	2572	2233	2572	2233	2572	2233

Note: The independent variables in specifications (2), (4), (6) and (8) are in one-year lags. All regressions with economy and year fixed effects. Constants are omitted to save space. Standard errors in brackets are adjusted for clustering across partner economies. *FTA* is a dummy for China's FTA in force at present (1 represents the economy being China's FTA partner, otherwise 0). *Y* is for partner's real per capita GDP in logarithm.

*Significant at 10%, **Significant at 5%, ***Significant at 1%, ****Significant at 13%.

TABLE 8 China's FTA partnership and GVC linkages: Based on matched sample (China's partners divided into four groups)

	Forward linkage				Backward linkage			
	C_dep		*P_dep*		*C_dep*		*P_dep*	
	(1)	(2)	(3)	(4)	(5)	(7)	(6)	(8)
Y_H	1.257***	0.906***	0.060*	0.033	0.032	0.006	1.034*	0.154
	(0.480)	(0.340)	(0.033)	(0.020)	(0.030)	(0.007)	(0.610)	(0.466)
Y_MH	0.361*	0.459**	0.005	0.004	0.000	0.003	0.185	0.191
	(0.203)	(0.200)	(0.005)	(0.004)	(0.008)	(0.004)	(0.229)	(0.281)
Y_LM	0.324**	0.377**	0.004	0.002	0.004	0.000	0.275	0.247
	(0.138)	(0.149)	(0.004)	(0.003)	(0.005)	(0.002)	(0.203)	(0.264)
FTA	0.817**	0.474	0.003	−0.000	−0.003	0.004	0.587	0.550
	(0.367)	(0.309)	(0.006)	(0.007)	(0.010)	(0.009)	(0.500)	(0.488)
*Y_H*FTA*	1.400*	1.471*	0.094**	0.066**	0.048*	0.002	1.888	1.469
	(0.845)	(0.776)	(0.039)	(0.026)	(0.029)	(0.018)	(1.551)	(1.438)
*Y_MH*FTA*	0.161	0.091	0.022	−0.006	0.089*	0.025*	−0.043	−0.346
	(0.687)	(0.541)	(0.018)	(0.016)	(0.050)	(0.013)	(0.712)	(0.573)
*Y_LM*FTA*	0.235	0.428	0.041**	0.023*	0.084***	0.053***	−0.185	−0.262
	(0.387)	(0.334)	(0.017)	(0.013)	(0.025)	(0.018)	(0.524)	(0.498)
adj. R^2	0.436	0.456	0.070	0.053	0.076	0.020	0.359	0.305
p	.000	.000	.007	.001	.000	.000	.000	.000
N	2563	2226	2572	2233	2572	2233	2572	2233

Note: The independent variables in specifications (2), (4), (6) and (8) are in one-year lags. All regressions with economy and year fixed effects. Constants are omitted to save space. Standard errors in brackets are adjusted for clustering across partner economies. *FTA* is a dummy for China's FTA in force at present (1 represents the economy being China's FTA partner, otherwise 0). *Y_H* = 1 for high-end group, 0 for others; *Y_MH* = 1 for mid-high-end group, 0 for others; *Y_LM* = 1 for low-mid-end group, 0 for others.

*Significant at 10%, **Significant at 5%, ***Significant at 1%.

First, we instrument the FTA dummies with their lags and use the 2SLS (two-stage least square) method for parameter estimation.[19] Tables 5 and 6 confirm our argument that the endogeneity issue is not serious. The results are similar to those in Table 3.[20] Hence, our previous fixed effects estimates are robust against endogeneity.[21]

Second, we adopt the propensity score matching (PSM) approach to address the endogeneity issue (Caliendo & Kopeinig, 2008; Rosenbaum & Rubin, 1983). From specification (1), differences in the FTA-induced impacts on GVC linkages might be due to other factors rather than the establishment of an FTA. That is, the sample of China's FTA partners and the sample of China's non-FTA partners might be different in terms of their probability of signing an FTA with China. They might be noncomparable samples. To deal with this, we use PSM method to imitate a randomised experiment with a treatment group and a control group. The treatment group includes partners that have signed an FTA with China, while the control group includes those that have never signed an FTA with China, but are very similar to the former group, in terms of their probability to sign an FTA with China. To the extent that non-matched samples are more diverse and less comparable than matched samples, the impact of FTA on GVC linkages will be lower when the sample is restricted to matched partners.

We first estimate a probit model on the probability of a partner signing an FTA with China. We estimate the following regression:

$$\begin{aligned} Pr\left(FTA-CHN_{it}=1\right) &= \Phi(\alpha+\beta_1 Y_{it}+\beta_2 GDP_{it}+\beta_3 Upstreamness_{it} \\ &\quad +\beta_4 Downstreamness_{it}+\beta_5 Resource_{it}+\lambda_t), \end{aligned} \tag{4}$$

where $\Phi(\cdot)$ is the cumulative distribution function of the standard normal random variable; Y_{it} and GDP_{it} are the partner country i's real per capita GDP (in logarithm) and real GDP (in logarithm), respectively; $Upstreamness_{it}$ and $Downstreamness_{it}$ are the partner country i's GVC position indices, respectively;[22] $Resource_{it}$ denotes the partner country i's resource abundance, and λ_t denotes year dummies.

[19]The literature (Barro, 2015,2016; Cameron and Trivedi, 2005) proposes the lagged regressors as instruments. Moreover, we use panel data as Baier and Bergstrand (2007) did, which can draw reliable inferences about the FTA impact.

[20]All results are based on the user-written Stata command *xtivreg2* (Schaffer, 2010). The Sanderson–Windmeijer multivariate *F* test of excluded instruments (which is a modification and improvement of the Angrist-Pischke *F*-test) displayed in Tables 5 and 6 underlines the relevance of the instruments selected in the first stage. The null hypothesis of the test is rejected in all specifications. The C-test for endogeneity does not reject the null hypothesis that the specified endogenous regressors can actually be treated as exogenous (except for the first model of Table 5 and the last model of Table 6), even though the 2SLS regressions produce results supporting our previous findings.

[21]We also instrument the FTA between China and its partner using the total number of FTAs that China's partner has signed (separately) with other economies excluding China. According to the domino effect theory of FTAs (Jaimovich and Baldwin, 2012), we expect that the more FTAs there are between China's partner and other economies excluding China, the greater possibility that the partner will sign an FTA with China to avoid trade diversion effects (Chen and Joshi, 2010; Orefice and Rocha, 2014). But, the results are not satisfactory, probably because the domino effect theory does not apply to China.

[22]Based on the methodology proposed by Antràs and Chor (2013,2018), Miller and Temurshoev (2017), we calculate output upstreamness and input downstreamness using the Eora trans-national IO data.

After propensity scores are obtained, they are used as criteria to match China's FTA partners with similar countries that have never signed an FTA with China.[23] Finally, to test the impact of an FTA partnership on China's bilateral GVC linkages, the sample of matched pairs is used in the regression with Equation (1). The results are presented in Tables 7 and 8. It can be seen that the previous findings are not challenged. Therefore, the results of these regressions support our hypothesis.

5.3 | Robustness checks

Tables 3 and 4 are our baseline regressions. In order to test for robustness, we now address the issues regarding contemporaneously cross-sectional correlation, spatial dependence, the omitted variable bias and subgroup variation.

First, the contemporaneously cross-sectional correlation could lead to biases in test results, especially in the standard error estimation. The fixed effects regressions in Tables 3 and 4 only produce standard errors clustered by one dimension, that is partner economy. Such clustering accounts for time serial autocorrelation. In order to address both cross-sectional correlation and time serial autocorrelation, we need to cluster by both partner economy and year. We obtain such clustered standard errors following the instructions of Petersen (2009). The results in Table A3 and Table A4 in the Appendix S1 show that all the coefficients remain unchanged, and the standard errors differ very little from the baseline[24], which indicates that the cross-sectional dependence is weak. The significant coefficients in the benchmark one-dimensional clustering regressions are still significant in the two-dimensional clustering regressions.[25] No findings go against the results of our baseline regressions.

Second, we control for spatial dependence (Neumayer & Plumper, 2010). Spatial dependence is ubiquitous in international economic relations and interactions. This is also true for the interaction or interdependence between China's FTA partners and non- FTA partners, which possibly induces the GVC diversion. In other words, among the geographically or economically close countries, non-FTA partners (compared with FTA ones) might lose from other countries' FTAs with China due to GVC diversion. We use spatial lags of the FTA dummy in the estimation to test the validity of this idea. We create spatial lags using the instructions of Neumayer and Plumper (2010),[26], and use the inverse geographic distance (population-weighted bilateral distance, CEPII) to construct the weighting matrix following the literature (e.g. Fuchs & Klann, 2013). The coefficients on the spatially lagged FTA dummies are expected to be negative if GVC diversion exists. However, the results are mixed: Some coefficients are positive while others are negative, but most of them do not reach statistical significance at conventional levels (see Appendix S1: Tables A5 and A6).[27] Moreover, adding the spatially lagged FTA dummy does not alter the signs or the magnitudes of the coefficients on the FTA interaction terms in the previous fixed effects regressions.

[23]The matching is done by using a kernel estimator. After the matching, the standardised (%) bias across covariates significantly drops.

[24]All results are obtained with Stata command *cluster2* by Petersen (2009).

[25]We also implement the multi-way clustering technique of Cameron et al. (2011) and cluster by year, partner and product, as well as by year, partner and sector, based on the user-written Stata command *cgmreg*. Taking this approach does not affect our main findings of the baseline regressions (results available from the authors upon request).

[26]We use the Stata command *spmon* of Neumayer and Plumper (2010) to create spatial lags.

[27]In some specifications, the inclusion of spatial lag even weakens the goodness of fit (R^2 becomes smaller).

Third, we check for the existence of omitted variable bias. One particular variable that may have a significant impact on GVC linkage is the bilateral direct investment between China and its partners. We obtain the aggregate data on China's inward and outward FDI by source and destination from the CEIC Data Manager. Our expectation is that the inward FDI would chiefly increase foreign shares in China's total value added, while the outward FDI tends to raise China's shares in partners' total value added. Taken together, the two-way investment is expected to strengthen the mutual GVC dependence between China and its partners. We include the one-year lag of FDI in the regressions. However, the results in Appendix S1: Tables A7, A8, A9 and A10 show that the impact of FDI is either statistically insignificant at conventional levels or displays wrong signs. Nevertheless, the main conclusions of the baseline regressions remain unchallenged.[28] In addition, to further control the possible impact of a partner's economic scale, which has already been accounted for at least partially by the country fixed effects, we add partner's GDP size to the benchmark model of Equation (1). In most cases, the scale effects are not significant. We also add to the benchmark model the partner's geographical distance (interacted with FTA) from China,[29] and find that the impact on GVC linkages is largely significantly negative as expected. Finally, we add to the benchmark model the tariffs applied by China to its partners and those applied to China by its partners, respectively,[30] and find no significant impact on GVC linkages. However, all these tactics have not challenged the previous basic findings, which remain valid.

Furthermore, to address the potential problem regarding the grouping of the sample economies, we drop the resource-dependent countries (as a whole, or group by group in terms of resource type or income level), still find no changes in the previous findings (see Appendix S1: Tables A11 and A12, where we drop the resource-dependent countries as a whole). And finally, the FTAs in the real world are actually heterogeneous in terms of the coverage and liberalisation level. Some only focus on trade in goods, some include both trade in goods and trade in services, while others cover not only trade but also other areas including investment and intellectual property rights protection. It can be imagined that the GVC linkages might be sensitive to the heterogeneity of FTAs. But for China (especially in the period of 1990–2015), the situation is not serious hence we skip this issue in the analysis.[31]

5.4 | Product and sector level analysis

The above analyses are conducted at the national level. In the real world, some FTAs function as or evolve from a form of partial economic integration on a sectoral/product basis.[32] In this part, we decompose the products into four categories and divide the sectors into 25 groups.

[28]In some specifications, the inclusion of lagged FDI variable has weakened the goodness of fit (R^2 becomes smaller).

[29]As the distance between China and the partner does not change with time, we introduce the interaction term of distance and FTA to account for the impact of distance on GVC linkages.

[30]The bilateral weighted average tariffs are obtained from the World Bank database https://wits.worldbank.org/WITS/WITS/Restricted/Login.aspx.

[31]In addition, since most of the models have quite high explanatory powers, we stick to the ordinary regression analysis rather than pursuing a nonlinear transformation in the limited dependent variable.

[32]For instance, European Union traces its origins partly from the European Coal and Steel Community, particularly for coal and steel sectors. Therefore, whether for the ex-ante negotiation and arrangement or for the ex-post-performance evaluation, it is necessary to investigate what the existing or potential FTA would look like and how it would develop if the heterogeneity of products or sectors is considered.

Pearson correlation is presented in Appendix S1: Table A13. In terms of backward linkage and at the product level, on the one hand, we find that China exhibits stronger dependence on richer partners, and on the other hand, the richer partners also exhibits stronger dependence on China. The correlation coefficients for the latter case are much smaller than for the former, and this is especially true for domestic use products (see Appendix S1: Table A14). An analysis of forward linkage reveals that the correlations between China's dependence and a partner's income level are different across products. The correlation is insignificant for final products, positive for exported intermediates and negative for intermediates for domestic use. But, richer partners are more dependent on China for any kind of product.

The sectoral Pearson correlation results are displayed in the remaining rows of Appendix S1: Table A13. The situation in terms of backward linkage is similar to that at the product level, which is not surprising. One thing of note is that rich partners are less dependent on China for services.[33] Then, we move to forward linkage. For all of the 25 sectors, the higher-income economies are more dependent on China. For the four manufacturing sectors, that is textiles and wearing apparel, electricity, gas and water, transport equipment and other manufacturing, the dependence of China on rich partners is most salient. But for service sectors, such as finance, public administration, education, health and other services, private households and others, China is less dependent on richer partners. In such sectors as textiles and wearing apparel, electrical and machinery, and transport equipment, we find a strong mutual GVC dependence between China and developed countries.[34]

The subgroup estimation results for products and usages are reported in Appendix S1: Tables A15–A22.[35] Conclusions from Appendix S1: Tables A15, A17, A19 and A21 resemble those from Table 3. For most cases, China has stronger forward GVC linkage with more developed partners, while the more developed partners have stronger backward GVC linkage with China.[36] There are indeed some subtle variations in the income and FTA effects across product usage and category. When backward linkage is used, the dependence is stronger in exported products than domestic ones. When forward linkage is used, the dependence is stronger in domestic products than exported ones.

Appendix S1: Tables A23 and A24 report the results for 25 sectors.[37] In most cases, the coefficients on the income term and the FTA interaction term are positive but not necessarily significant. The asymmetry of China-partner dependence is clear again. The partner dependence is much stronger than China's dependence and dominates the backward-type linkage, while China's dependence is much stronger than the partner dependence and dominates the forward-type linkage.

Appendix S1: Tables A25–A28 use income dummies. Appendix S1: Table A25 reveals that China has closer GVC linkages with higher-end economies in the majority of sectors. The results in Appendix S1: Table A28 resonate with previous results on partner dependence. In Appendix

[33]This is partly because services in China are less open to the outside world.

[34]The textiles and wearing apparel sector, which is China's traditional comparative advantage sector accounting for 26.1% of China's final goods export and 8.92% of China's intermediate goods export in 2015. Electrical and machinery accounted for over 13.85% of China's total output and over 30% of China's final and intermediate goods export, respectively, while 'Transport Equipment' took up nearly 4.23% of China's total output in 2015. These two sectors altogether accounted for more than 11% of China's value added and over 16% of China's intermediate goods for domestic use. See Appendix S1: Table A14.

[35]In what follows, the major results are based on fixed effects estimation.

[36]However, most of the coefficients are statistically insignificant.

[37]We omitted some results for brevity.

S1: Table A27, we find that as long as there exists an FTA partnership and the partner does not fall into the poorest category, China is significantly positively dependent on its partners across most sectors.

6 | CONCLUSION

In this study, we propose a theory on how a developing country's GVC linkages with partners are affected by partners' position on the GVCs and the characteristics of the FTAs, and use data from China to validate our hypothesis. Both the backward- and the forward-type GVC linkages are considered. We find that a trading partner's income level is positively associated with its GVC linkages with China, and that forming an FTA partnership with China will increase a high-income country's dependence on China, but such GVC promoting effect does not exist for China's low-income FTA partners. The results are quite robust against different model specifications and sector/product-level analyses.

Our research can help to understand how China has been involved and will continue to participate in the GVCs step by step, especially from the aspect of FTA partner selection and FTA arrangement. The findings in the paper have policy implications. For a country with a low position in GVCs like China, forming upward vertical FTAs with higher-income partners is a better alternative to enhance its engagement in GVCs than forming horizontal or downward vertical FTAs with low- or lower-income partners. However, the vertical-type FTA is likely to levy asymmetric impacts on its member economies. Those at the low end of a GVC would be locked in the low end without successful learning by doing. For them, the challenge is how to absorb the development benefits and to effectively hedge the low-end lock-in risks simultaneously, so as to successfully climb up the GVC and evolve into a high-end economy. The economy at the low end of a GVC should also be cautious of low-end loss if its climbing up fails. Otherwise, instead of solving the problem of low-end lock-in, it will suffer that low-end loss.

Our empirical analysis is based on China's experience. Assuredly, the lesson learned from China could to a certain degree be China specific. The size of China could move the balance of power in FTA negotiations. The industrial capacity and industrial policy of China could also act on the relationship between FTA and GVC. However, the theoretical argument leading to our hypothesis does not involve any particularity of China, such as its size or location. Hence, presumably, we have reason to believe that results in the paper are likely to be informative for other developing economies, those large ones in particular, to plan their FTAs and improve their GVC status.

Ideally, a comprehensive study with all countries involved can control for country-pair-wise (i.e. both parties in the FTA agreement) heterogeneities, hence are able to offer better-informed policy recommendations. We leave this topic for future research. Another promising avenue for future research, unaddressed in the study but also of particular interest, is to investigate how the impact of FTA is transmitted to GVC linkages.

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DATA AVAILABILITY STATEMENT

All the data can be available from the corresponding author upon request.

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SUPPORTING INFORMATION

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