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Global value chains, wages, employment and labour production in China: A regional approach

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ABSTRACT

In this study we analyse the relationship of trade and global value chains (GVCs) to the labour market in 31 Chinese provinces for 25 sectors, by means of a system of structural equations. We firstly distinguish between provincial value chains (PVCs) and interprovincial value chains (PRVCs) in order to outline their distribution and evolution over time. Then, we investigate to what extent participation in GVCs, PVCs and PRVCs – along with trading in final goods and services – is associated with labour market outcomes, i.e., wages, employment and labour production. The results suggest that provinces/sectors with greater export penetration have higher employment and labour production, but lower wages. On the other hand, however, GVCs are found to impede growth in employment and labour production.

1. Introduction

China has now become the 'world's factory', with solid and extensive engagement in international trade (it accounted for 16.3 % of global exports in 2020 according to the UN Comtrade database). At the same time, there has been a steady increase in production fragmentation worldwide, with the rise of global value chains (GVCs) (Johnson and Noguera, 2012; Kee and Tang, 2016; Szymczak and Wolszczak-Derlacz, 2022; Wang et al., 2013). These represent "*a series of stages involved in producing a product or service that is sold to consumers, with each stage adding value, and with at least two stages being produced in different countries*" (Antràs, 2020). China is necessarily a crucial player in GVCs, not only in regional free trade agreements like ACFTA, ASEAN, ChAFTA (Yang and Martinez-Zarzoso, 2014; Zhang and Wang, 2015). The aim of the 'One-Belt One-Road' initiative (OBOR) undertaken by the Chinese government at the end of 2013 was in fact to step up trade (Guo et al., 2017; Wolszczak-Derlacz and Lu, 2022; Yu et al., 2020).

By entailing a sharp fragmentation of production processes across borders, GVCs may significantly affect domestic labour market outcomes, usually represented by employment, labour production and wages (Autor et al., 2013; Baldwin and Yan, 2021; Bamber et al., 2014; Banga, 2022; Caraballo and Jiang, 2016; Lu et al., 2019; Opazo-Basáez et al., 2021; Shepherd, 2013; Taglioni and Winkler, 2016). In the presence of GVCs, indeed, the labour content associated with a country's traditional trade (i.e., with trade in final goods and services) is no longer of only two types (i.e., domestic labour embodied in exports and foreign labour embodied in imports). Other categories of employment have to be considered, such as foreign labour embodied in exports, domestic labour embodied in imports and third-country labour embodied in a country's imports (Jiang, 2015). Therefore, even though the relocation of production abroad can be expected to decrease employment, reduce wages and increase labour production in offshoring economies, and to raise employment and wages in production-base countries (Banga, 2022; Caraballo and Jiang, 2016; Lu et al., 2019; Newfarmer and Sztajerowska, 2012; Opazo-Basáez et al., 2021; Shepherd, 2013; Taglioni and Winkler, 2016), the impact of the international division of labour on labour market outcomes is ambiguous. In a general equilibrium perspective, labour market outcomes are affected by unobserved local shocks to productivity and labour supply (Adao et al., 2018). Moreover, in the presence of mobility frictions to labour movement across markets, employment, labour production and wages adjust differently across industries, space, and over time (Caliendo et al., 2019).

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In this framework, despite the large body of literature that has analysed the experience of China in GVCs (see, for instance, the work of Ge et al., 2020; Kohl, 2019; Wang et al., 2020; Xie et al., 2021), the consequences of participation in GVCs on the country's labour market have been less investigated. In particular, research in this field is mostly concentrated at the enterprise level and, due to the lack of recent data, limited to the first decade of the century, as with the works of Lü et al. (2018), Lu et al. (2019), Li et al. (2017), Wang et al. (2022) and Ge et al. (2018). Moreover, to the best of our knowledge, no study has explored the impact of GVCs on employment, labour production and wages simultaneously, overlooking the decoupling between labour production and wages (and the associated impact on the labour demand and employment) that has been observed in the country in last decades (Li et al., 2012; Gil-Alana et al., 2020), although with provincial differences (Chen et al., 2009). At the same time, no empirical evidence has assessed how these are jointly affected by participation in domestic value chains (DVCs), i.e., in value chains that involve only domestic production partners.

In order to fill this gap, the present paper assesses the relationship between China's value chain participation and the labour market by distinguishing between GVCs and DVCs. More specifically, we break down the latter into 'provincial value chains' (PVCs) and 'interprovincial value chains' (PRVCs) – according to whether the various stages of production occur exclusively within the same province or across different Chinese provinces, respectively – and assess their evolution over time. This allowed to take into account the large variation in the overseas dependency, industrial structure, and economic size across the Chinese provinces. In other words, we do not consider China as a single entity but investigate the labour market outcomes following a provincial level perspective.[2] Then, we investigate the extent to which involvement in GVCs, PVCs and PRVCs – other than with trading in final goods and services – may be associated with labour market outcomes. Accordingly, we propose the following research questions:

- How is participation in GVCs, PVCs and PRVCs distributed across Chinese provinces and how did it change over time?
- To what extent does trade in final goods and services is associated with employment, labour production and wages in China?
- To what extent does China's participation in GVCs, PVCs and PRVCs relates to employment, labour production and wages?

The novelty of our paper is therefore twofold. On the one hand, it simultaneously assesses the three channels of the GVC-labour market outcome nexus from the Chinese perspective. To this end, the paper exploits seemingly unrelated regression estimates (SURE) to a system of equations. On the other hand, such an assessment is carried out by taking into account PVCs and PRVCs, i.e., the economic differences occurring within and between Chinese provinces.

The paper is organised as follows. The second section reviews the relevant literature on GVCs, labour market outcomes and China. The third part describes the data and methodology, while the fourth section presents the empirical analysis and some extensions and robustness checks. Finally, Section 5 sets out a discussion of the findings, and concludes.

[2] In response to the slowdown in China's economic growth and the reshaping of the global value chain caused by the Sino-U.S. trade dispute, Covid-19 and "derisking" policies, the Chinese government proposed the "Dual Circular" economy policy in 2020 (Ciuriak, 2023; Yifu and Wang, 2022). It mainly focused on building its domestic market and industrial chain (the most representative of which is the chip industry). Therefore, the research on DVCs and labour market have also shown increasing policy and economic significance.

2. Literature review

2.1. Labour market and GVCs

While there is no single consensus theory of GVCs, their importance within international trade is well recognised in the theoretical and empirical literature (Shingal, 2015; Szymczak and Wolszczak-Derlacz, 2022). On the one hand, GVCs allow firms from offshoring economies – generally represented by developed countries – to access lower labour costs. On the other, they offer new opportunities for production-base countries – mostly emerging and transition economies – to integrate into global trade, enabling them to specialise in specific products or tasks within a value chain, rather than having to develop entire industries (World Bank (Washington, District of Columbia), 2019). In both cases, hence, the implications for a country's job market are relevant and, to a large extent, intrinsically associated with the position occupied by that country within the value chain, i.e., whether its participation occurs in a backward GVC (i.e., it uses imported inputs to produce and then export) or in a forward GVC (i.e., it exports raw materials and intermediate inputs for further processing and export by other countries) (Constantinescu et al., 2019). These implications generally appear through three main channels, namely, (i) employment, (ii) labour production, and (iii) wages (Farole, 2016).

The impact of GVCs on domestic employment – typically investigated in the literature in terms of job opportunities and job reallocation (Kabeer and Mahmud, 2004; Nadvi et al., 2004) – is still controversial (Carneiro et al., 2023). Although GVCs can be expected to stimulate faster employment growth and job creation in the case of forward GVCs, the relocation of job opportunities abroad may decrease the labour demand in countries typically participating in backward GVCs (Bamber et al., 2014). However, the job losses in the latter can be offset by the existence of employment depending on export activities and foreign affiliates (Shepherd, 2013). Participation in GVCs may also lead to domestic job reallocation between occupations, by redefining the comparative advantage of countries across tasks rather than industries. Hence, following the standard Heckscher-Ohlin model, GVCs are expected to foster a shift in the jobs embodied in exports from low-skilled towards higher-skilled labour content (OECD, 2016; World Bank Group et al., 2017). On these grounds, however, Caraballo and Jiang (2016) find that participation in GVCs creates more domestic than foreign employment, although the jobs related to exports remain low-skilled. Moreover, in the presence of labour market frictions, the job reallocation induced by offshoring may bring short-term unemployment, as suggested by Grossman and Rossi-Hansberg (2008) and Crinò (2010).

By favouring the international division of labour, GVCs may create new opportunities for raising labour production through specialisation, both in the case of backward and forward GVCs (Banga, 2022; OECD, 2012; Opazo-Basáez et al., 2021; Taglioni and Winkler, 2016). In the first case, countries may achieve productivity gains through structural and compositional changes, i.e., by accessing new inputs, in addition to the comparative advantages of production specialisation (Criscuolo and Timmis, 2017; Grossman and Rossi-Hansberg, 2006). By contrast, countries participating in forward GVCs make productivity gains thanks to greater input variety, learning, knowledge and technology dissemination (Baldwin and Robert-Nicoud, 2014; Constantinescu et al., 2019). In particular, significant benefits may derive from productivity spillovers to local firms in connection with the domestic presence of multinational enterprises (MNEs), stemming from competition, imitation and learning effects (Pittiglio et al., 2016).

Finally, gains in labour production associated with GVCs may, in turn, affect the wages of local workers, which should rise in keeping with their higher marginal productivity (Pittiglio et al., 2015). Furthermore, as argued above, the firms involved in GVCs are vectors of technological upgrading, which increases the relative demand for skilled labour, and hence the relative wages of these workers. Similar effects derive from the presence of MNEs, which are expected to pay relatively higher wages

for skilled jobs: this wage increase may spill over to domestic firms insofar as they raise wages to prevent their best, most qualified workers from moving to MNEs (Muñoz-Bullón and Sánchez-Bueno, 2013). Otherwise, foreign firms might 'steal' the best, most skilled workers, provoking a labour market crowding-out effect and lowering both wages and skill levels in the domestic firms (Aitken et al., 1996; Chen et al., 2011; Nguyen et al., 2020). The possibility for workers in GVC firms to obtain higher wages seems to be empirically confirmed, as in the works of Baldwin and Yan (2021) and Shepherd (2013). One exception is the work of Nikulin and Wolszczak-Derlacz (2022), which affirms, in data covering 18 EU countries, GVCs impede wages increases especially for medium-skilled/educated and female workers. Again, the impact depends on the relative GVC position, as has been shown by Szymczak and Wolszczak-Derlacz (2022). Moreover, higher wages can also be associated with greater wage inequality between skilled and unskilled occupations, and weakened bargaining power for the low-skilled, possibly leading to a degradation in their working conditions (Abd Rahman et al., 2022; Wang et al., 2021).

2.2. Previous empirical evidence on China

Despite the large amount of empirical literature exploring China's participation in GVCs, contributions concerning the related impact on the local labour market are surprisingly limited to date. Among them, it is worth mentioning the work of Lü et al. (2018), who adopt the methods of propensity score matching, difference in differences and generalised propensity score, applied to enterprise data from 2000 to 2006. Their results show that GVC participation can promote employment through exports, the substitution of intermediate goods and the global division of labour of MNEs. By using the same data and methodology, Lu et al. (2019) find that participation in GVCs has a positive impact on wages, especially in capital-intensive and foreign-funded enterprises. Similar findings are reported by Li et al. (2017). Based on structural decomposition analysis, Wang et al. (2021) investigate the extent to which GVC participation and position may affect wage inequality (average wage and the proportion of skilled workers). The authors use cross-border and cross-regional input–output tables from 2007 to 2012 to show that GVC participation as such has no significant impact, while upgrading the enterprise industrial chain has aggravated wage inequality. Similarly, Wang et al. (2022) employ Chinese enterprise-level data from 2000 to 2006, but include environmental costs in their panel regression model. They find that being part of a GVC impedes employment growth, especially in the eastern regions and for women and low-skilled workers. Ge et al. (2018) use 2000–2007 Chinese firm-level data to measure the embeddedness of firms in GVCs, and employ the entropy balancing method to assess the effect of GVC participation on enterprise productivity. Their findings show the positive effect of GVC membership on productivity, especially in capital- and technology-intensive industries and in general trading enterprises. They also confirm that R&D and government subsidies strengthen the productivity effect of participation in GVCs. Finally, Chen et al. (2021) consider environmental governance, obtaining the opposite result at the overall corporate level. They adopt a propensity score matching estimation with 2000–2006 data, finding also that the impact of GVCs on corporate productivity is heterogeneous between profitable companies (promoting) and loss-making companies (hindering). However, for lack of recent data, these works are limited to the first decade of the century.

The literature also offers some sectoral analysis, as in the case of Wu et al. (2021), who employ WIOD2014 data to discuss the negative impact of the decoupling of GVCs between China and the US on employment at the sector level.

The above literature review shows how the empirical evidence concerning the nexus between GVCs and China's labour market is mostly concentrated at the enterprise level and limited to the first decade of the century. More importantly, it does not provide evidence about the impact of GVCs on employment, labour production and wages considered jointly. Similarly, no research has been conducted as regards taking into account the economic differences across the Chinese provinces. The present contribution attempts, therefore, to overcome these limitations using a structural equations model to investigate simultaneously the labour market outcomes. This econometric approach - although already adopted in the empirical literature on GVCs (see, for instance, Mehta, 2021 and Szymczak and Wolszczak-Derlacz, 2022) - has never been employed in the Chinese case.

3. Materials and methods

3.1. Data sources and integration

The data used in this paper comprise value chain participation indexes for Chinese provinces and a set of labour market outcome variables. They cover 31 provinces and 25 sectors for the years 2012, 2015 and 2017. Specifically, the labour market variables considered are based on the China Labour Economy Database in the EPS China Data platform, the Chinese Multi-Regional Input-Output Tables (CMRIO) in Carbon Emission Account & Datasets, and World Development Indicators. Additional variables related to R&D are collated from the Chinese Provincial Statistical Yearbooks. The GVC, PRVC and PVC participation indexes are obtained from CMRIO, the Multi-Regional Input-Output table published by the Asian Development Bank (ADB-MRIO), while bilateral sectoral trade between the provinces and other countries is drawn from the China Industries Trade dataset in the EPS China Data platform.

Since the sector classifications of the original data are inconsistent, we first integrate data into the same 25 sectors (see Table A.1 in the Appendix for details). We then construct the Chinese labour market outcomes dataset and the value chain participation indexes for the various provinces.

To build the labour market outcomes dataset, we first calculate exports, value added, average wages, number of employees and the ratio of female employees for each sector in all Chinese provinces, using CMRIO and China Labour Economy Database for the years 2012, 2015 and 2017. To adjust for inflation, we derive real value added and real average wages using the GDP deflator (2015=100), obtained from the World Development Indicators. Finally, we calculate average labour production as real value added over employment.[3] To produce the provincial value chain participation indexes, we integrate CMRIO into ADB-MRIO, thus obtaining the provincial multi-regional input-output table (CEMRIO), so as to calculate the provincial value chain participation indexes using CEMRIO and the method of Wang et al. (2017), following five steps:

Step 1: Since the classifications of the final use portions of CMRIO and ADB-MRIO are inconsistent, we sum them to obtain the full final use of each area.
Step 2: We calculate the ratios between single provincial elements and the corresponding national element in the same sector from the intermediate and final portions of CMRIO, respectively. Then we reduce the Chinese national elements in ADB-MRIO to the province level, taking the ratio from CMRIO and the value from ADB-MRIO.
Step 3: Since it is impossible to obtain the relationship between China's provinces and other economies at sector level using CMRIO and ADB-MRIO, we take the import and export data from the China Industries Trade dataset in the EPS China Data platform to obtain the ratios of each province's bilateral sector trade with each economy and the rest of the world (ROW). Due to the lack of some Chinese

[3] In fact, we calculate average labour production. In order to calculate total factor productivity, one needs the data of value added, fixed assets, the number of employees, prices and materials. See, for example, Aguirre (2022), where the author calculates productivity at the firm-level.

bilateral sector trade data (especially in service sectors), we follow Gao and Wang (2020); that is, we use the ratio of the entire manufacturing industry in lieu of the missing data.[4] Then, depending on each province's share of the entire Chinese economy, the value of each foreign element in the intermediate and final portions of ADB-MRIO is divided to obtain the values of each province's trade with other economies in the final CEMRIO.[5]

Step 4: To keep the proportions of value added and total investment in Chinese provinces the same as in CMRIO, we use the Biproportional Scaling Method (RAS) to balance the CEMRIO obtained in the first three steps. After verification, we find that it is not applicable because the error is too large (for instance, the minimum sum of squares of deviations in 2012 is about 1.6e+40, much greater than 0.001).[6] Therefore, we obtain the value added from the total output and intermediate input of CEMRIO, according to the previous steps. Finally, we combine these elements to obtain the final CEMRIO covering 31 provinces and 62 countries (including ROW) for 25 sectors.

Step 5: Using the methods of Wang et al. (2017), we calculate the GVC, PRVC and PVC participation indexes of each province-sector.

Similar methods are employed in province-level analysis (whole sector), and the RAS method is suitable for this part.

To gauge provincial participation in the various value chains, we follow Wang et al. (2017), dividing MRIO into the GVC and the domestic value chain (DVC) and constructing the formula for calculating participation. On this basis, we further divide DVC into PVC and PRVC.

First, we replace the domestic and provincial input coefficient matrixes with A^D and A^{DP}, respectively :[7]

$$A^D = \begin{bmatrix} A^{11} & 0 & 0 & \cdots & 0 \\ 0 & A^{22} & 0 & \cdots & 0 \\ 0 & 0 & A^{33} & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & A^{CC} \end{bmatrix} \tag{1}$$

where A^{11} represents China's domestic input coefficient matrix and A^{CC} – country/economy C's domestic input coefficient.

To better illustrate the situation of the provinces, we expanded A^{11} into a matrix (31 × 31) and took the number of 'provinces' in other economies as 1. The new expanded A^D is shown as:

$$A^D = \begin{bmatrix} A^{11}_{11} & A^{11}_{12} & \cdots & A^{11}_{1P} & 0 & 0 & \cdots & 0 \\ A^{11}_{21} & A^{11}_{22} & \cdots & A^{11}_{2P} & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ A^{11}_{P1} & A^{11}_{P2} & \cdots & A^{11}_{PP} & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & A^{22} & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & 0 & A^{33} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & A^{CC} \end{bmatrix} \tag{2}$$

Accordingly, the provincial input coefficient matrix is given as:

$$A^{DP} = \begin{bmatrix} A^{11}_{11} & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 \\ 0 & A^{11}_{22} & \cdots & 0 & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & A^{11}_{PP} & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & A^{22} & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & 0 & A^{33} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & A^{CC} \end{bmatrix} \tag{3}$$

where A^{11}_{PP} represents the provincial input coefficient in province P.

The total output can be shown as:

$$\begin{aligned} &X = AX + Y \\ &(I - A)X = Y \\ &X = (I - A)^{-1}Y = BY \end{aligned} \tag{4}$$

where X represents the total output matrix, A – the input coefficient matrix, Y – the final goods matrix, I – the Identity matrix and B – the Leontief inverse matrix. Dividing A^D and A^F (foreign input coefficient matrix) by A, Eq. (4) can be written as:

$$X = A^D X + A^F X + Y$$

Hence:

$$\begin{aligned} &\left(I - A^D\right)X = A^F X + Y \\ &X = \left(I - A^D\right)^{-1}A^F X + \left(I - A^D\right)^{-1}Y \\ &X = LA^F X + LY \\ &BY = LA^F BY + LY \end{aligned} \tag{5}$$

where A^D denotes the domestic input coefficient matrix, A^F – the foreign input coefficient matrix, and L – the domestic Leontief inverse matrix.

Converting Y into a diagonal matrix and multiplying both sides of Eq. (5) by $\widehat{VA}$, the new equation becomes:

$$\begin{aligned} &\widehat{VA}B\widehat{Y} = \widehat{VA}LA^F B\widehat{Y} + \widehat{VA}L\widehat{Y} \\ &\widehat{VA}B\widehat{Y} = \widehat{VA}LA^F B\widehat{Y} + \widehat{VA}L\_P\widehat{Y} + \widehat{VA}(L - L\_P)\widehat{Y} \end{aligned} \tag{6}$$

where: $\widehat{VA}$ denotes the diagonal matrix of value added, L_P – the provincial Leontief inverse matrix, $\widehat{VA}LA^F B\widehat{Y}$ is related to GVC, $\widehat{VA}L\widehat{Y}$ to DVC, $\widehat{VA}L\_P\widehat{Y}$ to PVC, and $\widehat{VA}(L - L\_P)\widehat{Y}$ to PRVC.

Adopting the approach of Wang et al. (2017), we extended the forward (value added) and backward value chain participation (final product) to PVC and PRVC. Thus, value added can be represented as:

$$VA' = \widehat{VA}BY = \widehat{VA}LA^F BY + \widehat{VA}L\_PY + \widehat{VA}(L - L\_P)Y \tag{7}$$

where VA' denotes the transposed matrix of value added, $\widehat{VA}LA^F BY$ – the value added related to GVC, $\widehat{VA}L\_PY$ – the value added related to PVC, and $\widehat{VA}(L - L\_P)Y$ – the value added related to PRVC.

Similarly, the final product value can be written as:

$$Y' = VAB\widehat{Y} = VALA^F B\widehat{Y} + VAL\_P\widehat{Y} + VA(L - L\_P)\widehat{Y} \tag{8}$$

where Y' represents the transposed matrix of the final product value, $VALA^F B\widehat{Y}$ – the final product value related to GVC, $VAL\_P\widehat{Y}$ – the final product value related to PVC, and $VA(L - L\_P)\widehat{Y}$ – the final product value related to PRVC.

Finally, the participation indexes of various value chains are presented as:

[4] CMRIO provides information on province i in China, and the relationship between China and country j can be obtained in ADB-MRIO. For the final CEMRIO table, we need to obtain the link between province i and country j. So we use the ratio of province i in the imports/exports of China and country j as the 'bridge' between CMRIO and ADB-MRIO (all at sectoral level).

[5] All values and ratios are at the bilateral sectoral level.

[6] Details are provided in the R file in the supplementary materials.

[7] In our final CEMRIO there are C (63) countries and P (31) provinces. The sector details are not shown here.

$$
\begin{aligned}
GVC\_forward &= \widehat{VA}LA^{F}BY/VA^{'}\\
DVC\_forward &= \widehat{VA}LY/VA^{'}\\
PVC\_forward &= \widehat{VA}L\_PY/VA^{'}\\
PRVC\_forward &= \widehat{VA}(L-L\_P)Y/VA^{'}\\
GVC\_backward &= VALA^{F}B\widehat{Y}/Y^{'}\\
DVC\_backward &= VAL\widehat{Y}/Y^{'}\\
PVC\_backward &= VAL\_P\widehat{Y}/Y^{'}\\
PRVC\_backward &= VA(L-L\_P)\widehat{Y}\ /Y^{'}
\end{aligned}
\tag{9}
$$

where *GVC_forward* is the forward participation index in GVC, *DVC_forward* – in DVC, *PVC_forward* – in PVC, *PRVC_forward* – in PRVC, *GVC_backward* is the backward participation index in GVC, *DVC_backward* – in DVC, *PVC_backward* – in PVC, and *PRVC_backward* – in PRVC.

3.2. Descriptive statistics

As noted, we integrate all sectors to obtain the participation of provinces in different value chains. To better show the inter-regional differences within China, we draw different maps based on the participation indexes. This section discusses China's forward and backward participation maps for 2017 (those for 2012 and 2015 are given in the Appendix).[8] In particular, Fig. 1 shows the forward participation indexes of Chinese provinces in global (GVC - upper left map), domestic (DVC - bottom left map), provincial (PVC - upper right map), and interprovincial (PRVC - bottom right map) value chains in 2017. Furthermore, the darker colours correspond to the higher participation indexes.

First, by comparing the GVC (upper left map) and DVC (bottom left map) forward participation index maps, we can see that Chinese provinces are generally characterised by greater participation in domestic value chains (around 0.7- 0.9) than in global chains (around 0.1- 0.3).

Second, we analyse the regional differences within the participation map of each value chain and added discover some interesting findings as follows:

(1) As regards GVCs (upper left map), the participation of the eastern provinces (such as Jiangsu, Zhejiang and Shanghai) and southern coastal provinces (e.g., Guangdong) is significantly greater than that of the central and western regions (the name and location of each province are shown in Fig. A.1). These high-participation regions coincide with China's two leading economic, transport and manufacturing centres (the Yangtze and Pearl River deltas) (Fang et al., 2020; Fangqu and Jun, 2019). The figure suggests, therefore, that the value added created by coastal provinces is more heavily related to global production through exports of intermediate products and that these provinces are essential participants in the worldwide production chain.
(2) At the same time, the pattern of domestic value chain participation (bottom left map) is the opposite.
(3) As mentioned in the previous subchapter, DVC can be divided into provincial (PVC) and interprovincial value chains (PRVC). The PVC map (upper right map) shows that the southwestern region strongly participates in provincial value chains. The value added created by one province in this region enters its production activities mainly through intermediate products and is not closely related to production in other provinces. This is also in accordance with the fact that the southwest is one of China's more underdeveloped areas and is at high altitude (the Qinghai Tibet Plateau), where infrastructure is limited.
(4) The northeast provinces have the highest interprovincial participation index (bottom right map), but their GVC participation (upper left map) is not at the forefront. This difference suggests that while these provinces are not heavily involved in global production, they are closely related to production in the rest of China. Moreover, this situation also reflects the fact that this region has always been marked by heavy industry and significant energy production (Zhang et al., 2018), and its value added is more extensively related to the productive activity of other provinces. However, the region's opening to overseas trade has lagged far behind that of the eastern coastal areas since reform and opening up. The potential reasons are multi aspects, such as continuous population loss (Meng and Long, 2022), the lack of seaports (Olson and Morgan, 1992), and less attractiveness for foreign direct investment (Zhang and Cai, 2020).

On the one hand, Fig. 2 shows a similar situation as regards backward participation in various value chains to Fig. 1 in two aspects. First, looking at the GVC, PVC and PRVC maps, one sees that the production of final products depends heavily on the value added created by productive factors within each province (index around 0.6 - 0.8), with only a minor part coming from other provinces (around 0 - 0.3) and countries (around 0.1 - 0.2). Second, the patterns for GVC (upper left map) and DVC (bottom left map) participation are similar to Fig. 1: the eastern and southern coastal provinces have high backward participation in GVCs, which indicates that these provinces absorb more foreign factors of production, embodied in intermediate products, in the production of final products.

On the other hand, the backward and forward participation rates within and between provinces differ. The central region shows a low degree of backward PRVC participation (bottom right map) and a high degree of backward PVC participation (upper right map), which indicates that the production of final products in this part of China depends more heavily on within-province productive factors.

Examining these two figures, along with Figs. A.2 to A.5 in the Appendix, we attempt to analyse the trend of changes in the participation of various value chains (GVC, DVC, PVC, PRVC) in multiple provinces in China during 2012–2017.

First, one observes that regarding GVCs (upper left maps in each figure), the coastal provinces (with higher GVC participation indexes than others) have always played a pioneering role in China's international opening up. We also find that, except for a few central and western regions and Liaoning Province (Dandong Port),[9] most provinces' backward GVC participation indexes in 2017 were lower than in 2012, and the change in forward GVC participation was similar. In our view, this change is likely to reflect China's industrial upgrading (the relocation of some processing industries, such as the garment industry), overcapacity, rising labour costs and the general decline in the share of GVCs in world trade during this period (Zhan et al., 2020).

Second, the trend in participation in domestic value chains (DVCs) is opposite to that in GVCs: the participation of most provinces increased between 2012 and 2017. This means that industrial ties inner-province or between provinces have become closer, thanks presumably to the steady improvement in domestic infrastructure (high-speed rail, expressways) (Kang et al., 2023; Zhu et al., 2016) and the transfer of some industries from the eastern to the central and western provinces (the Western China Development Programme).

Finally, with the DVC category, we explore the changes in PVC (upper right maps) and PRVC (bottom right maps) separately. These changes are complex. Therefore, we also calculate the ranking values of provinces, relying on our combined data as another measurement parameter. Specifically, the ranking and value of the participation of the

[8] The involvement of Chinese provinces in GVCs decreased gradually between 2012 and 2017.

[9] In 2012, the opening of the Northeast East Railway Passage, which runs through 13 cities in the eastern part of Northeast China, made the eastern regions of Heilongjiang and Jilin provinces the hinterland of Dandong Port (https://zh.m.wikipedia.org/wiki/%E4%B8%B9%E4%B8%9C%E6%B8%AF, downloaded 29 Nov 2022).

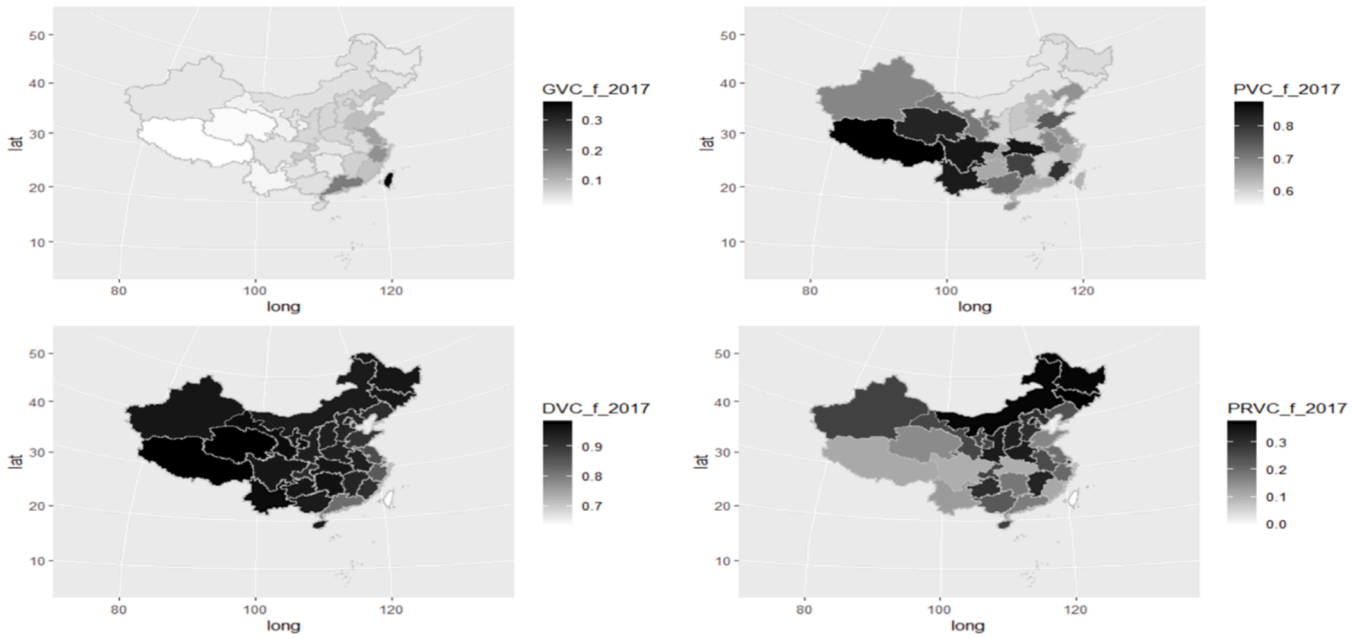

Fig. 1. Chinese provincial participation indexes in 2017 (Forward). Source: own compilation.

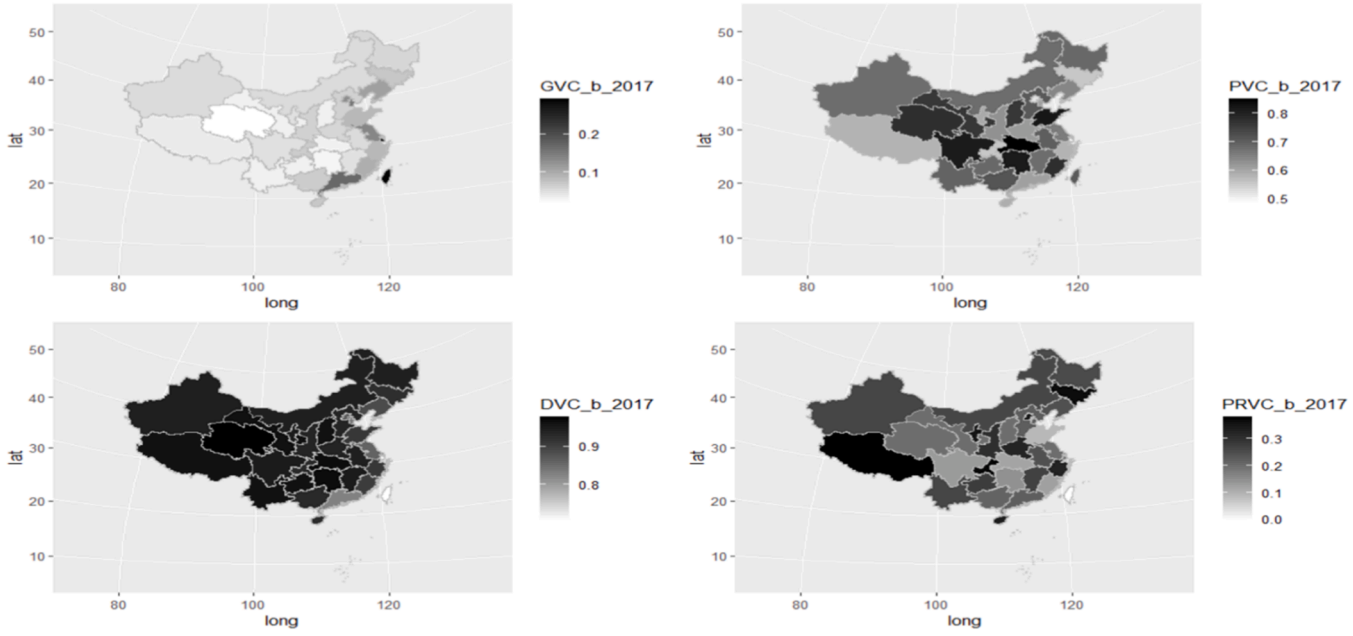

Fig. 2. Chinese provincial participation indexes in 2017 (Backward). Source: own compilation.

provinces have changed over the period. Some areas ranking at the top in PVC and the bottom in PRVC (such as Hubei and Sichuan) showed little change. This means that the industrial agglomeration of these areas is relatively strong, and connectivity with other provinces is not high. The reason is that in the context of the "Central Rise Strategy", these provinces have established their own "one hour (or 100 km)" industrial clusters around the provincial capital cities (Chengdu, Wuhan) (Ke and Feser, 2010). On the other hand, Jilin Province (on the north-eastern border) showed a significant decline in its forward and backward PVC ranking, as well as the sharpest gain in PRVC ranking, showing that under the Northeast Area Revitalisation Plan, this province – a traditional heavy industry base and coal producer – is increasingly connected with other parts of China.

3.3. *Model specification*

In Section 3.1 we describe data and the methods that allow us to calculate different measures of GVC. The data used in this analysis comprise value chain participation indexes for Chinese provinces and a set of labour market outcome variables. Specifically we calculate GVC and divide DVA into province and interprovinces indexes. Here we present the methods that we employ in order to answer our research questions. We employ a system of structural equations that allow us to identify the relationship between different covariates and wages, employment and labour production simultaneously. A similar approach (but with two equations, for wages and employment) is presented in Szymczak and Wolszczak-Derlacz (2022) and applied to the analysis of world GVC flows.

$$lnWage_{i,p,t} = \alpha + \beta_1 lnEmp_{i,p,t} + \beta_2 lnProd_{i,p,t} + +\beta_3 lnTrade_{i,p,t} + \beta_4 GVC_{i,p,t} + \gamma_i + \delta_p + \theta_t + \epsilon_{i,p,t} \quad (10)$$

$$lnEmp_{i,p,t} = \alpha + \beta_1 lnWage_{i,p,t} + \beta_2 lnProd_{i,p,t} + +\beta_3 lnTrade_{i,p,t} + \beta_4 GVC_{i,p,t} + \gamma_i + \delta_p + \theta_t + \epsilon_{i,p,t} \quad (11)$$

$$lnProd_{i,p,t} = \alpha + \beta_1 lnWage_{i,p,t} + \beta_2 lnEmp_{i,p,t} + +\beta_3 lnTrade_{i,p,t} + \beta_4 GVC_{i,p,t} + \gamma_i + \delta_p + \theta_t + \epsilon_{i,p,t} \quad (12)$$

where: i denotes sector, p – province, and t – time.

The wage regression is given by Eq. (10), where wages (the log of real wages in 2015 prices) are regressed on employment (*Emp* - Number of employed persons in urban units at the end of the year), labour production (*Prod* - Real value added per employee), trade (*Trade* - Export), and GVC penetration. *GVC* is measured either by foreign backward or forward linkage. We also consider domestic value chains, which can be decomposed into provincial (*PVC*) and interprovincial (*PRVC*) participation. Analogously, Eq. (11) refers to employment and Eq. (12) to labour production. For detail, the variable definition, data source and descriptive statistics can be checked in Tables A.2 and A.3.

All specifications include industry (γ_i), province (δ_p) and time (θ_t) fixed effects. The inclusion of individual (fixed) effects should solve several problems, such as the more intensive GVC involvement of certain sectors (e.g., those with relatively lower wages). Moreover, GVC, wages, employment, and average labour production may all be affected by time-varying shocks (global economic shocks or an advancement in technology). Since we want to estimate simultaneously three regressions: wages, employment and labour production, with the same covariates, we adopt the seemingly unrelated regression (SURE) developed by Zellner (1962), which uses the asymptotically efficient, feasible, generalised least-squares estimator. We assume that the matrix of variances and covariances of the errors is constant in all the equations, to avoid presumptions that the errors can be heteroskedastic and correlated differently in each equation.

4. The results

Table 1 presents the results from regressions (10), (11) and (12) estimated simultaneously. There is a full set of individual effects to control for sector, province and time trends.

The upper panel refers to the wage regression. As expected, wages are higher in sectors with higher average labour production. We also find that wages are positively associated with the level of employment, possibly because higher employment (i.e., less unemployment) forces firms to raise salaries in order to attract and retain workers.

Findings from the employment regressions (middle panel) suggest that the level of employment is positively correlated with wages and negatively with average labour production. On the one hand, indeed, higher wages are likely to prompt people to migrate from rural to urban areas and also to attract urban workers from other provinces or industries. In the short run, the increase in the labour supply should lower wages. This, in turn, would translate into output expansion, but would also increase demand for labour, at least partially offsetting the depressing effect and instead putting upward pressure on wages. In our case, the results suggest that the factors for an increase in wages outweighed those for a decrease.

Finally, average labour production (bottom panel) is negatively correlated with employment and positively by wages. Indeed, as expected, an increase in employment leads to a decrease in average labour production. As shown above, the increase in employment can be due to higher wages, which therefore negatively associate with average labour production.

Table 1
Estimation of wages, employment and labour production regressions.

	Forward linkages		Backward linkages	
	(1)	(2)	(3)	(4)
Dependent variable: lnWage				
lnEmp	0.105***	0.100***	0.100***	0.099***
	[0.006]	[0.006]	[0.005]	[0.005]
lnProd	0.139***	0.131***	0.127***	0.126***
	[0.007]	[0.008]	[0.006]	[0.006]
lnTrade	−0.005*	−0.003	−0.006**	−0.006**
	[0.002]	[0.002]	[0.002]	[0.002]
GVC	−0.004		0.046***	
	[0.115]		[0.016]	
PVC		0.017		−0.02
		[0.115]		[0.015]
PRVC		−0.093		0.024***
		[0.123]		[0.009]
Dependent variable: lnEmp				
lnWage	1.973***	1.561***	2.000***	1.964***
	[0.105]	[0.097]	[0.102]	[0.101]
lnProd	−1.051***	−1.061***	−0.977***	−0.974***
	[0.025]	[0.022]	[0.024]	[0.024]
lnTrade	0.138***	0.121***	0.146***	0.150***
	[0.010]	[0.009]	[0.010]	[0.010]
GVC	−1.015**		−0.794***	
	[0.501]		[0.069]	
PVC		1.057**		0.548***
		[0.457]		[0.065]
PRVC		3.740***		−0.460***
		[0.481]		[0.039]
Dependent variable: lnProd				
lnEmp	−0.636***	−0.702***	−0.619***	−0.620***
	[0.015]	[0.015]	[0.015]	[0.015]
lnWage	1.580***	1.360***	1.607***	1.592***
	[0.081]	[0.078]	[0.081]	[0.081]
lnTrade	0.096***	0.090***	0.099***	0.103***
	[0.008]	[0.008]	[0.008]	[0.008]
GVC	−1.073***		−0.646***	
	[0.389]		[0.055]	
PVC		1.067***		0.389***
		[0.370]		[0.053]
PRVC		3.056***		−0.371***
		[0.390]		[0.031]
N	1541	1541	1760	1760
R^2 (*lnWage*)	0.8	0.8	0.79	0.79
R^2 (*lnEmp*)	0.82	0.85	0.81	0.81
R^2 (*lnProd*)	0.64	0.67	0.61	0.61

Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Industry, province and time dummies included in all specifications, SURE regressions.
Source: own compilation.

Concerning the variables of traditional trade and value chains, we find mixed results along the three specifications, suggesting that trade in final goods and services cannot explain the complexity of today's global production chains.

Consider the economic theory of comparative advantage in conjunction with the Heckscher-Ohlin model, which states that countries with higher export penetration have higher employment and productivity, but lower wages. If a country has higher export penetration, it means that it is producing and selling more goods and services abroad. This, in turn, implies that there is a greater demand for labour in exporting companies, which increases employment and productivity in the country. However, wages may be lower because exporting companies must compete in the global marketplace, which limits their ability to set higher prices for their products. Moreover, if labour is cheaper in other countries, companies may choose to move their production to those countries to reduce costs, which could also contribute to lower wages. Our results show that wages are indeed negatively associated with traditional trade and positively with global and

interprovincial value chains, although only at the backward level. This partially confirms the findings of Szymczak and Wolszczak-Derlacz (2022) and, for China, the empirical evidence provided by Lu et al. (2019). It is also important to interpret not only statistical significance of obtained coefficient but also its economic meaning. We concentrate here on the variables we are mainly interested in: trade and different measures of GVC. For example if export (traditional trade) rises by 1 % the wages decreases by 0.006 %. In backward specification the rise of GVC by 1 unit is associated with the rise of wages by 4.6 %. and respectively for PRVC by 2.4 % (coefficients from columns 3 and 4 of upper panel of Table 1).

In contrast, employment and labour production are positively correlated with trade, PVCs and forward PRVCs but negatively with GVCs and backward PRVCs. Specifically, the rise of traditional trade by 1 % is associated with the rise of employment by 0.15 % and labour production by 0.103 % (coefficients from column 4 of middle and lower panel of Table 1). Further the rise of GVC/PVC by 0.1 unit is related to drop/rise of employment and labour production by up to 10 %, respectively. As far as interprovince chains are considered (PRVC) there are differences in sign and magnitude of coefficient whether forward or backward linkages are taken into account. The magnitude of coefficients is higher for forward linkages. If forward PRVC rises by 0.1 unit employment/labour production rises by 37/30.6 % respectively. For backward linkages the rise of PVC by 0.1 unit is associated with the drop of employment/labour production by 4.6/3.7 % (middle and lower panel of column 4 from Table 1).

Based on these interpretations we see that contrary to traditional trade (export) the associations between GVC/PVC/PRVC and labour market outcomes are not trivial.

Concerning employment, the results are in line with the findings of Wang et al. (2022) but not with those of Lü et al. (2018). Overall, they seem to confirm the general expectations that participation in forward value chains fosters job creation, whereas participation in backward value chains reduces the demand for labour. In particular, they provide evidence that an increase in trade (exports) has, to some extent, prompted enterprises to hire additional staff to serve growing external demand. However, the rise in GVC participation has indeed restrained employment growth. China's growing participation in GVCs stems in part from the rise in the cost of labour. For example, between 2012 and 2017, some industries (footwear, garments) sought to transfer some production lines to Vietnam, India and other low-wage countries (Chen and De Lombaerde, 2013). Given China's comparative advantage in some intermediates and essentials, this strengthened the country's industrial ties with these regions (greater GVC participation), at the expense of jobs. In contrast, the increase in PVCs means expectations of additional new production links in the province, creating new employment opportunities. Regarding labour production, our results are more in line with those of Chen et al. (2021) than with those of Ge et al. (2018). In particular, the positive impact of trade means that enterprises may step up production in order to produce more goods to serve expanding external demand. Hence, the increase in Chinese GVC participation has impeded the growth of average labour production. Owing to 'low-end technology lock-in', China is still at the low-value-added end of GVCs (production, assembly, etc.). Even though Chinese labour production has gained a great deal in recent decades, increased participation in low-value-added industries impedes productivity gains. Meanwhile, the greater involvement in GVCs has deepened the country's dependence on them. On the one hand, there are policy limitations on the introduction or absorption of advanced technologies (e.g., export administration regulations). On the other hand, these products hinder the development and market of similar products in China, thus blocking productivity improvement (as in the field of high-end chips, high-end medical instruments, and precision machine tools). At the same time, greater PVC participation improves the industrial chain within provinces and lowers logistical costs and delivery time, thus enhancing productivity.

Some studies (Blanchard and Galí, 2007; Wang and Gunderson, 2011) have pointed out that wages can be subject to rigidities and can be influenced by factors such as the bargaining power of workers and employers and the "queue" caused by China's colossal workforce entering high-wage industries or regions. Thus, we re-estimate this regression by substituting lagged wages (Table A.4). The main results considering the association between GVCs and labour market outcomes stand similar to Table 1.

In order to be sure that our results are not biased, for example, by missing covariates or sector/province heterogeneity, we run a number of extensions and robustness checks (see next section).

5. Extensions and robustness

To extend the analysis, we augmented our basic specification with R&D expenditure and the ratio of female workers. Table 2 indicates that the increase in R&D investment is positively correlated with employment, average labour production and wages, especially the first two. R&D investment obviously helps to foster technological advances and more efficient production. In addition, it is also a factor for industrial upgrading, a reduction in energy consumption, more competitive products, expanded market demand (both domestically and internationally), and employment growth. In addition, the increase in R&D expenditure creates jobs directly, in R&D. It can be seen that the coefficients of our key variables (i.e., trade and our GVC measures) are very similar to the baseline regression.

Furthermore, a little more time is needed for average labour production to respond to the change in R&D expenditure (Rouvinen, 2002). We re-estimated the model by lagged R&D expenditure; the results are shown in Table A.5. Although some provinces in China lacked data on R&D expenditure at the industry level in the early years, the role of R&D investment in promoting wages, employment, and average labour production has once again been verified, and some of the absolute value of its effect has also increased. Moreover, the results considering the association between GVCs and labour market outcomes remain consistent with Table 2.

Table 3 presents the analogous estimations of three regressions with an additional covariate: the female ratio. The increase in the proportion of female workers is positively related to employment and average labour production, while negatively with wage growth. As regards employment, the higher proportion of women workers reflects not a decrease in the male work force but the movement of more women from the family to the labour market. China's 'one-child policy' in the last century certainly impeded population growth (Yang and Dunford, 2018), but, to a certain extent, it also improved the education of girls, helping to create conditions for women's access to skilled jobs. The young face tremendous economic pressure when they leave home to form a family (high housing prices, the need to support parents, educational expenses, etc.), which in a way, 'forces' women to participate in the labour market. However, the results on wages show continuing gender discrimination in the labour market, even though the rising proportion of women workers has not decreased average labour production. In the end, the results of this augmented regression for the impact of trade and GVCs are aligned with the baseline specification, confirming the foregoing conclusions.

Next, we estimate the regressions for manufacturing only (Table 4). Again, the results are very similar to the baseline. Finally, to ensure the results are not biased by a specific industry or province, we run the regression, leaving out one industry/province at a time. Tables A.6 and A.7 in the Appendix show the average value of each coefficient in 25 regressions for industry heterogeneity and 31 for province heterogeneity. Removing selected sectors and/or provinces does not alter the results.

Table 2
Estimation of wages, employment and labour production; added-covariate: R&D.

	Forward linkages		Backward linkages	
	(1)	(2)	(3)	(4)
Dependent variable: lnWage				
ln_RD	0.044***	0.046***	0.026***	0.024***
	[0.008]	[0.008]	[0.007]	[0.006]
lnEmp	0.021*	0.022*	0.050***	0.056***
	[0.011]	[0.012]	[0.009]	[0.010]
lnProd	0.069***	0.068***	0.066***	0.070***
	[0.010]	[0.011]	[0.010]	[0.010]
lnTrade	−0.003	−0.003	−0.008**	−0.008**
	[0.004]	[0.004]	[0.003]	[0.003]
GVC	0.037		0.024	
	[0.163]		[0.017]	
PVC		−0.032		−0.041*
		[0.163]		[0.021]
PRVC		−0.096		0.034**
		[0.172]		[0.014]
Dependent variable: lnEmp				
ln_RD	0.470***	0.396***	0.409***	0.384***
	[0.022]	[0.023]	[0.022]	[0.021]
lnWage	0.307*	0.301*	0.864***	0.892***
	[0.165]	[0.158]	[0.163]	[0.155]
lnProd	−0.402***	−0.570***	−0.521***	−0.571***
	[0.039]	[0.039]	[0.038]	[0.036]
lnTrade	0.057***	0.061***	0.072***	0.078***
	[0.014]	[0.013]	[0.014]	[0.013]
GVC	−0.01		−0.199***	
	[0.628]		[0.072]	
PVC		0.117		0.507***
		[0.602]		[0.084]
PRVC		1.860***		−0.485***
		[0.633]		[0.053]
Dependent variable: lnProd				
ln_RD	0.120***	0.112***	0.147***	0.174***
	[0.032]	[0.029]	[0.026]	[0.026]
lnEmp	−0.445***	−0.566***	−0.479***	−0.564***
	[0.043]	[0.039]	[0.035]	[0.036]
lnWage	1.131***	0.914***	1.063***	1.084***
	[0.170]	[0.155]	[0.155]	[0.153]
lnTrade	0.062***	0.062***	0.074***	0.076***
	[0.014]	[0.013]	[0.013]	[0.013]
GVC	−0.951		−0.288***	
	[0.659]		[0.069]	
PVC		0.79		0.424***
		[0.599]		[0.084]
PRVC		2.891***		−0.406***
		[0.621]		[0.054]
N	545	545	646	646
R^2 (*lnWage*)	0.85	0.85	0.84	0.84
R^2 (*lnEmp*)	0.88	0.89	0.86	0.87
R^2 (*lnProd*)	0.58	0.65	0.6	0.61

Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Industry, province and time dummies included in all specifications, SURE regressions.
Source: own compilation.

Table 3
Estimation of wages, employment and labour production; added-covariate: female ratio.

	Forward linkages		Backward linkages	
	(1)	(2)	(3)	(4)
Dependent variable: lnWage				
R_female	−0.004***	−0.004***	−0.005***	−0.005***
	[0.001]	[0.001]	[0.001]	[0.001]
lnEmp	0.110***	0.105***	0.107***	0.105***
	[0.006]	[0.006]	[0.005]	[0.005]
lnProd	0.141***	0.134***	0.130***	0.128***
	[0.007]	[0.008]	[0.006]	[0.006]
lnTrade	−0.005**	−0.003	−0.006**	−0.006**
	[0.002]	[0.002]	[0.002]	[0.002]
GVC	0.006		0.053***	
	[0.116]		[0.016]	
PVC		0.003		−0.018
		[0.116]		[0.015]
PRVC		−0.113		0.023***
		[0.124]		[0.009]
Dependent variable: lnEmp				
R_female	0.017***	0.014***	0.023***	0.020***
	[0.003]	[0.003]	[0.003]	[0.003]
lnWage	2.041***	1.631***	2.111***	2.067***
	[0.104]	[0.097]	[0.100]	[0.100]
lnProd	−1.047***	−1.056***	−0.969***	−0.966***
	[0.025]	[0.022]	[0.024]	[0.024]
lnTrade	0.134***	0.118***	0.139***	0.144***
	[0.010]	[0.009]	[0.010]	[0.010]
GVC	−0.848*		−0.796***	
	[0.502]		[0.068]	
PVC		0.937**		0.520***
		[0.459]		[0.065]
PRVC		3.556***		−0.444***
		[0.483]		[0.038]
Dependent variable: lnProd				
R_female	0.011***	0.010***	0.013***	0.011***
	[0.003]	[0.003]	[0.003]	[0.003]
lnEmp	−0.645***	−0.709***	−0.631***	−0.630***
	[0.015]	[0.015]	[0.015]	[0.015]
lnWage	1.619***	1.399***	1.664***	1.635***
	[0.082]	[0.079]	[0.081]	[0.081]
lnTrade	0.094***	0.089***	0.097***	0.101***
	[0.008]	[0.008]	[0.008]	[0.008]
GVC	−0.959**		−0.656***	
	[0.393]		[0.055]	
PVC		0.981***		0.379***
		[0.375]		[0.053]
PRVC		2.947***		−0.366***
		[0.395]		[0.031]
N	1540	1540	1759	1759
R^2 (*lnWage*)	0.8	0.8	0.79	0.8
R^2 (*lnEmp*)	0.82	0.85	0.82	0.82
R^2 (*lnProd*)	0.64	0.67	0.61	0.61

Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Industry, province and time dummies included in all specifications, SURE regressions.
Source: own compilation.

6. Conclusions

This paper discusses how trade and GVC participation are related to labour market outcomes in the provinces of China. It further considers the relationship of R&D spending and the proportion of women in the workforce.

Academic work on GVCs and labour market outcomes in China is not abundant. To the best of our knowledge, there is no comprehensive study of the association between participation in GVCs on wages, employment and average labour production. Furthermore, the research on China's GVC participation is concentrated at a national level. We investigated the GVC and labour market outcome database, including 25 sectors in 31 provinces, in 2012, 2015 and 2017. In line with a statistical analysis and the previous literature, this paper applies the seemingly unrelated regression method (SURE). Our main contribution is our comprehensive exploration of the correlation of trade and participation in global, provincial and interprovincial value chains on Chinese labour market outcomes, by sector and province.

Our principal findings are: 1) GVC participation diminished between 2012 and 2017 in every province; the high-participation areas are found mostly in the eastern and southern coastal regions; provincial value chains play a dominant role, while GVC participation is least extensive. 2) In terms of labour market outcomes, wages and employment are positively correlated, as are wages and labour production, while employment and labour production are related negatively. 3) The conflicting results concerning the labour market effects of traditional

Table 4
Estimation of wages, employment and labour production; manufacturing industries.

	Forward linkages		Backward linkages	
	(1)	(2)	(3)	(4)
Dependent variable: lnWage				
lnEmp	0.111***	0.110***	0.109***	0.109***
	[0.007]	[0.008]	[0.007]	[0.007]
lnProd	0.102***	0.099***	0.105***	0.105***
	[0.009]	[0.010]	[0.008]	[0.008]
lnTrade	−0.003	−0.001	−0.007*	−0.007*
	[0.004]	[0.004]	[0.004]	[0.004]
GVC	−0.05		0.022	
	[0.133]		[0.016]	
PVC		0.058		−0.021
		[0.133]		[0.016]
PRVC		−0.085		0.016
		[0.144]		[0.010]
Dependent variable: lnEmp				
lnWage	2.006***	1.572***	2.048***	2.017***
	[0.133]	[0.120]	[0.124]	[0.123]
lnProd	−0.899***	−0.933***	−0.863***	−0.847***
	[0.032]	[0.028]	[0.030]	[0.030]
lnTrade	0.220***	0.198***	0.209***	0.206***
	[0.016]	[0.014]	[0.015]	[0.015]
GVC	−1.833***		−0.520***	
	[0.561]		[0.070]	
PVC		1.975***		0.462***
		[0.500]		[0.069]
PRVC		4.576***		−0.342***
		[0.528]		[0.042]
Dependent variable: lnProd				
lnEmp	−0.635***	−0.739***	−0.603***	−0.608***
	[0.023]	[0.022]	[0.021]	[0.022]
lnWage	1.301***	1.130***	1.383***	1.401***
	[0.115]	[0.109]	[0.106]	[0.107]
lnTrade	0.158***	0.158***	0.140***	0.138***
	[0.014]	[0.013]	[0.013]	[0.013]
GVC	−1.738***		−0.480***	
	[0.471]		[0.058]	
PVC		1.888***		0.303***
		[0.444]		[0.060]
PRVC		4.019***		−0.284***
		[0.472]		[0.036]
N	909	909	1095	1095
R^2 (*lnWage*)	0.76	0.77	0.76	0.76
R^2 (*lnEmp*)	0.86	0.89	0.84	0.85
R^2 (*lnProd*)	0.56	0.61	0.55	0.55

Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Industry, province and time dummies included in all specifications, SURE regressions.
Source: own compilation.

foreign trade and of GVC participation show that trade cannot explain the complexity of today's global production chains. GVC participation impedes the growth of employment and average labour production, possibly owing to the lack of a labour cost advantage and to 'low-end technology lock-in'. In addition, the effects of PVCs and PRVCs on the labour-market outcome variables are less uniform. PVC participation has generally fostered gains in employment and average labour production. Further as far as economic significance is considered we find that association between GVC/PVC and PRVC and labour market outcomes is not trivial.

This study elucidates the different levels and changes in GVC, PRVC and PVC participation in single Chinese provinces. It provides a reference for studying the interrelation between national and international economies. It explores the correlation between trade and Chinese labour market outcome variables and helps explain the impact of varying degrees of value chain participation on the labour market, against the backdrop of the gradual loss of China's comparative advantage in labour costs and the industrial upgrading of the country.

Some limitations to this analysis must be acknowledged, however. First, is the fact that the employment data concern urban areas only, and additionally, data are not continuous (available only for the years 2012, 2015 and 2017) so the panel nature of the data cannot be fully exploited. Next, the data are at the sectoral level thus GVCs are observed at the sectoral level and not, e.g., at the firm level. Similarly, wages are the average sectoral wages, and productivity – average labour production. Furthermore, in our analysis we do not possess information about GVC position – the distance to final demand, which can also influence labour market outcomes as shown, e.g., by Szymczak et al. (2022).

We think these shortcomings are less important based on the availability of existing data and research sustainability. Specifically, China's urbanization process is approaching completion, and most of the added value of various industries in China is also borne by the urban working population. Rural populations generally have lower education and are becoming increasingly ageing. Using urban labour market data in this article has little impact on the relevant conclusions. Second, considering that the data of Chinese industrial enterprises will no longer be publicly disclosed after 2015, and the input-output tables within the world, Chinese provinces, and cities will be maintained and updated, the method applied in this paper for departmental-level DVCs provides relatively good scalability for subsequent related research. Most importantly, regarding industrial and labour market policies, the regional sector level is more fair and operable than implementing employment subsidies for enterprises.

As for studying the labour market at GVCs and DVCs locations, obtaining input-output tables from recent years and expanding the database would be more appropriate. This is because the restructuring of the global value chain and the dual circulation policy of the Chinese economy roughly began after the 2018 Sino-U.S. trade war.

Finally, the issues investigated in this paper carry implications for future research, which can be divided into two lines of inquiry. As one line, the study might well be extended to the impact of policy factors, or else refined, limiting it to specific products/industries (say, the chip production chain) or regions (regional value chains). Second, in view of the disruption of Chinese exports and global supply chains by the COVID-19 pandemic and the Sino-US trade conflict, one might fruitfully dedicate a follow-up study to the way in which these events impacted China's GVC participation and the Chinese labour market.

Author statement

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

Data availability

Data will be made available on request.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.strueco.2023.12.005.

Appendix

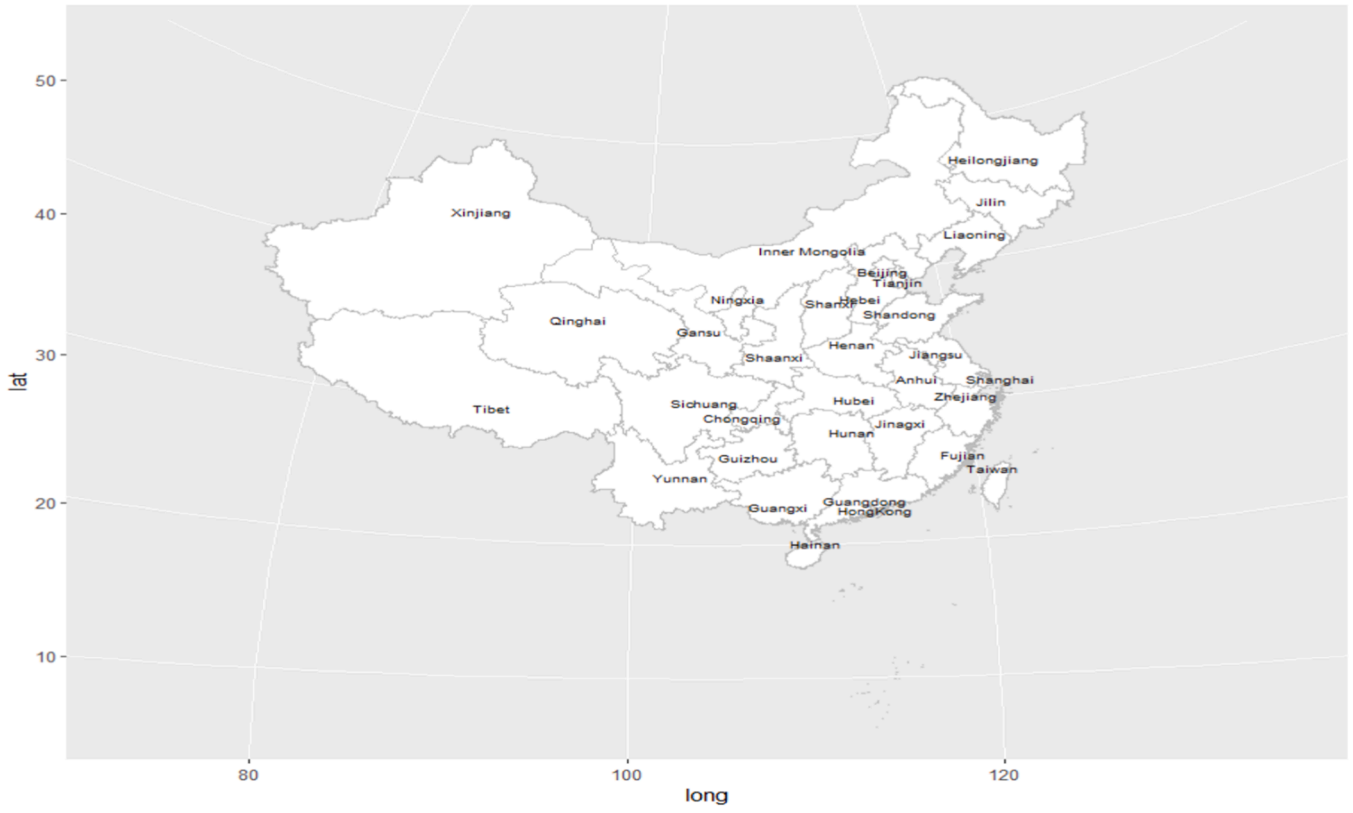

Fig. A.1. The provinces of China. Source: own compilation.

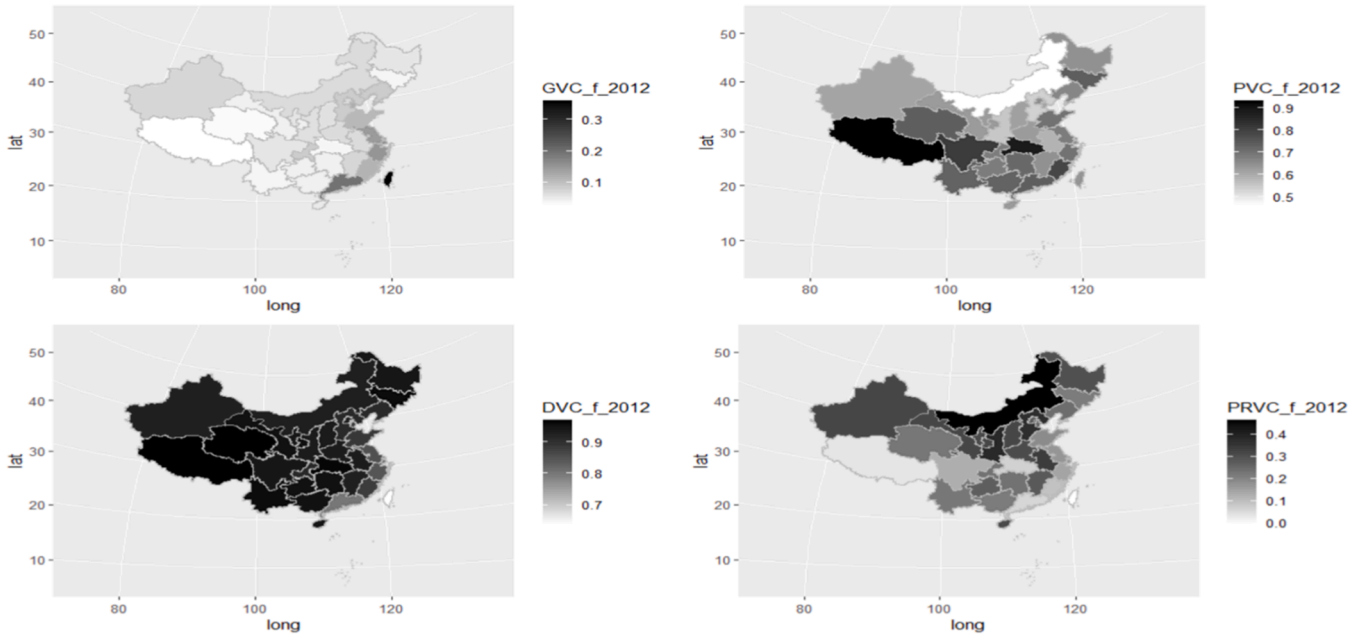

Fig. A.2. Provincial participation indexes, 2012 (Forward). Source: own compilation.

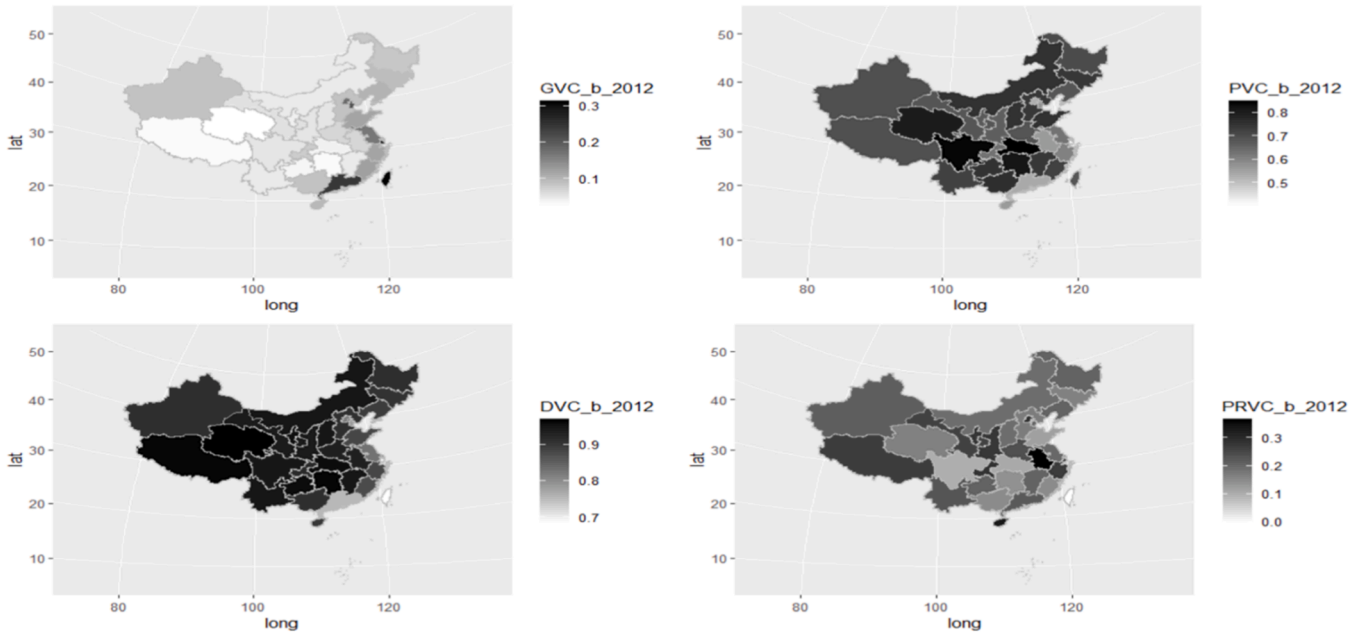

Fig. A.3. Provincial participation indexes, 2012 (Backward). Source: own compilation.

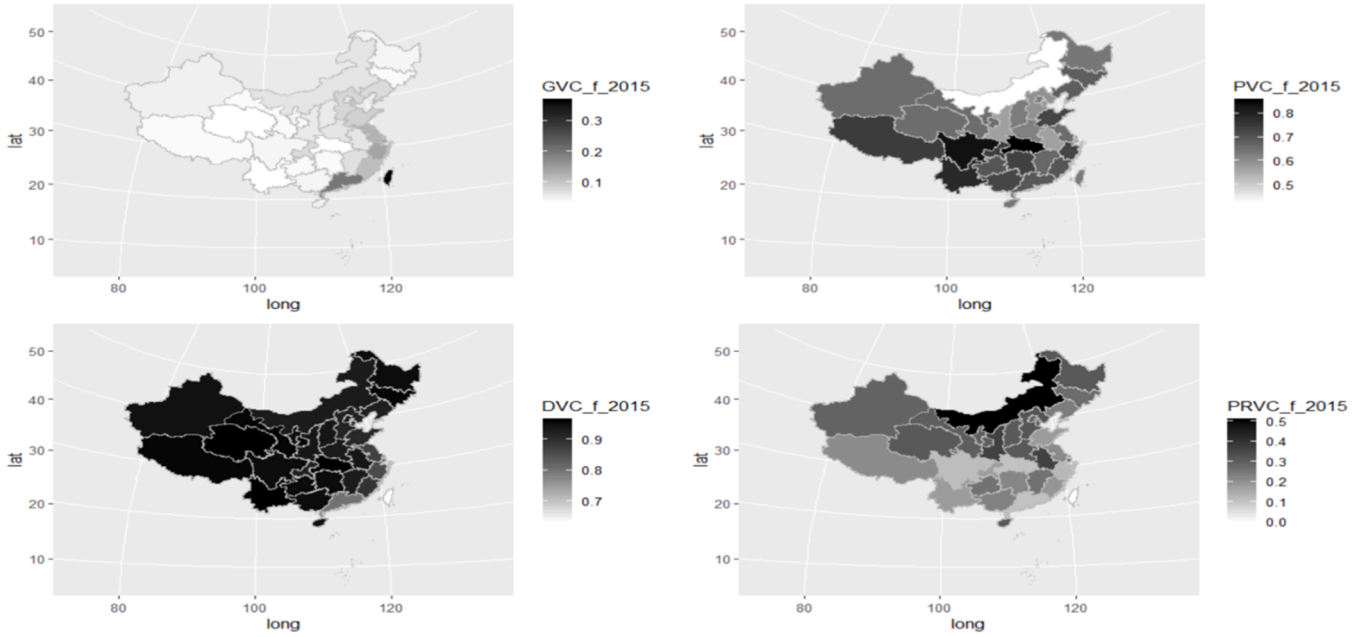

Fig. A.4. Provincial participation indexes, 2015 (Forward). Source: own compilation.

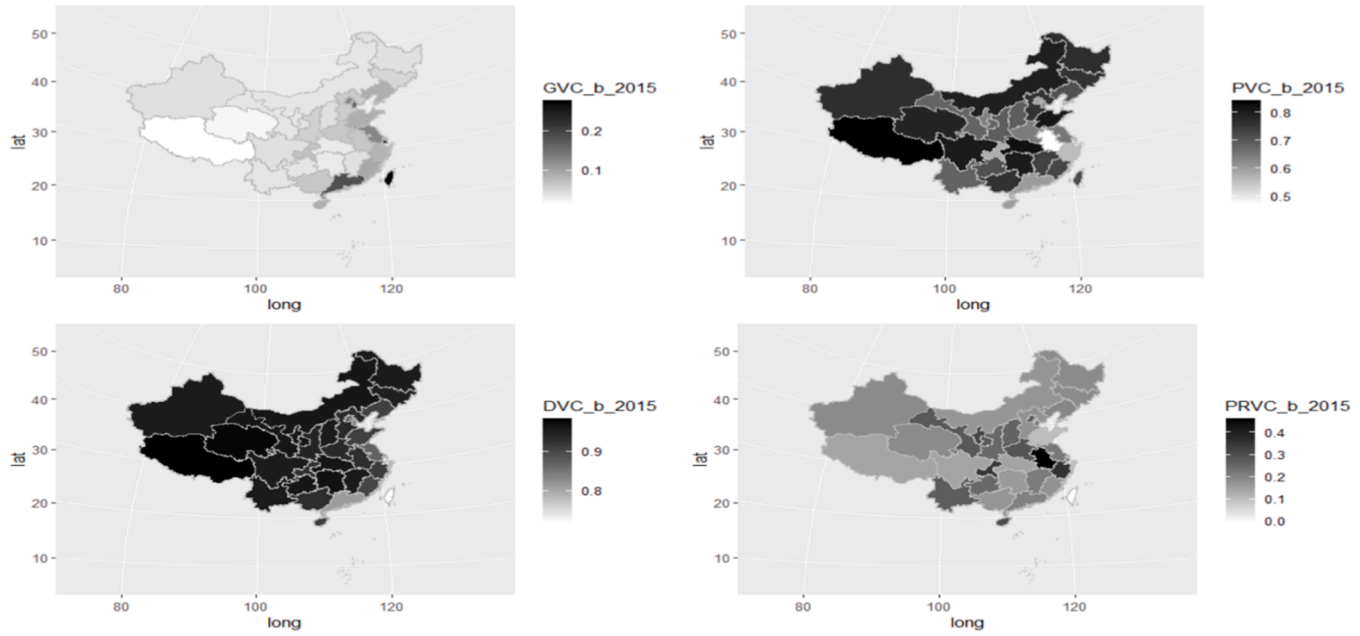

Fig. A.5. Provincial participation indexes, 2015 (Backward). Source: own compilation.

Table A.1
Sector classification integration table.

Sector ID	Sector	ADB-MRIO	CMRIO
1	Agricultural, forestry, animal husbandry and fishery products and services	1	1
2	Mining	2	2;3;4;5
3	Food and tobacco	3	6
4	Textile and garment industry	4;5	7;8
5	Wood products and furniture	6	9
6	Paper printing and cultural, educational and sporting goods	7	10
7	Petroleum, coking products and nuclear fuel processing products	8	11
8	Chemical products	9;10	12
9	Non-metallic mineral products	11	13
10	Metal smelting and metal products	12	14;15
11	General and special equipment	13	16;17;24
12	Transportation equipment	15	18
13	Electrical and optical equipment	14	19;20;21
14	Other manufactured products	16	22;23
15	Production and supply of electricity, heat, gas and water	17	25;26;27
16	Architecture	18	28
17	Wholesale and retail	19;20;21	29
18	Transportation, storage and postal service	23;24;25;26;27	30
19	Catering and accommodation	22	31
20	Finance	28	33
21	Real estate	29	34
22	Leasing and business services	30	35
23	Education	32	39
24	Health and social work	33	40
25	Other services	31;34;35	32;36;37;38;41;42

Notes: Due to space limitations, sector integration related to R&D, employment, trade, and other variables is not given here. The specific classification and integration process can be obtained in the do-file of Stata provided in the supplementary materials.
Source: Own compilation.

Table A.2
Variable definition and data source.

Variable	Definition	Data source
Wage	The real average wage in 2015 prices of employees in urban units (1000 Chinese yuan)	China Labour Economy Database / World Development Indicators
Emp	Number of employed persons in urban units at the end of the year (person)	China Labour Economy Database
Prod	Real value added per employee by sector and region in China (10,000 Chinese yuan per person)	CMRIO / China Labour Economy Database / World Development Indicators
Trade	Export by sector and region in China (10,000 Chinese yuan)	CMRIO

(*continued on next page*)

Table A.2 (*continued*)

Variable	Definition	Data source
Wage_lag	Previous year's real average wage of employees in urban units (1000 Chinese yuan)	China Labour Economy Database / World Development Indicators
RD	R&D Expenditures of industrial enterprises above the designated size by industrial sector (100 million yuan)	Chinese Provinces' Statistics Yearbooks
RD_lag	Previous year's R&D Expenditures of industrial enterprises above the designated size by industrial sector (100 million yuan)	Chinese Provinces' Statistics Yearbooks
R_female	The ratio of female employees in urban units at the end of the year (%)	China Labour Economy Database
GVC (forward)	Forward Global Value Chain participation index - the share of domestic value added generated from a province-sector's GVC activities through downstream firms in that province-sector's total added value	ADB-MRIO/ CMRIO/ China Industries Trade Data Set
PVC (forward)	Forward provincial value chain participation index - the share of PVC comments in the total value added	ADB-MRIO/ CMRIO/ China Industries Trade Data Set
PRVC (forward)	Forward inter-provincial value chain participation index - the share of PRVC comments in the total value added	ADB-MRIO/ CMRIO/ China Industries Trade Data Set
GVC (backward)	Backward Global Value Chain participation index - the share of domestic value added generated from a province-sector's GVC activities through upstream firms in that province-sector's final product value	ADB-MRIO/ CMRIO/ China Industries Trade Data Set
PVC (backward)	Backward provincial value chain participation index - the share of PVC comments in the final product value	ADB-MRIO/ CMRIO/ China Industries Trade Data Set
PRVC (backward)	Backward inter-provincial value chain participation index - the share of PRVC comments in the final product value	ADB-MRIO/ CMRIO/ China Industries Trade Data Set

Source: own compilation.

Table A.3
Descriptive statistics.

VarName	Obs	Mean	SD	Min	Median	Max
lnwage	2313	3.933	0.381	2.523	3.905	5.465
lnEmp	2313	11.260	1.781	0.000	11.559	15.244
lnProd	2310	3.760	1.026	−0.228	3.734	8.381
lnTrade	1766	12.117	3.026	−5.826	12.587	19.182
ln_RD	679	1.766	2.110	−7.581	1.868	7.042
R_female	2311	37.295	14.256	6.102	34.801	96.667
GVC (forward)	2068	0.073	0.067	0.000	0.058	0.615
PVC (forward)	2068	0.691	0.217	0.006	0.705	1.000
PRVC (forward)	2068	0.236	0.185	0.000	0.204	0.888
GVC (backward)	2325	0.127	0.374	0.001	0.061	10.684
PVC (backward)	2325	0.706	0.373	0.000	0.720	11.573
PRVC (backward)	2325	0.328	0.627	0.000	0.232	13.298

Source: Own compilation.

Table A.4
Estimation of lagged wages, employment and labour production regressions.

	Forward linkages		Backward linkages	
	(1)	(2)	(3)	(4)
Dependent variable: lnWage_lag				
lnEmp	0.097***	0.094***	0.092***	0.097***
	[0.006]	[0.006]	[0.005]	[0.005]
lnProd	0.134***	0.128***	0.124***	0.131***
	[0.007]	[0.008]	[0.006]	[0.006]
lnTrade	−0.003	−0.002	−0.004*	−0.006**
	[0.002]	[0.002]	[0.002]	[0.002]
GVC	−0.142		0.044***	
	[0.116]		[0.016]	
PVC		0.152		−0.048***
		[0.116]		[0.015]
PRVC		0.03		0.047***
		[0.124]		[0.009]
Dependent variable: lnEmp				
lnWage_lag	1.824***	1.462***	1.851***	1.933***
	[0.106]	[0.097]	[0.103]	[0.102]
lnProd	−1.048***	−1.060***	−0.975***	−0.979***
	[0.025]	[0.023]	[0.024]	[0.024]
lnTrade	0.139***	0.122***	0.147***	0.151***
	[0.010]	[0.009]	[0.010]	[0.010]
GVC	−0.8		−0.810***	
	[0.504]		[0.070]	
PVC		0.882*		0.606***
		[0.458]		[0.065]
PRVC		3.624***		−0.507***

(*continued on next page*)

Table A.4 (*continued*)

	Forward linkages		Backward linkages	
	(1)	(2)	(3)	(4)
		[0.483]		[0.039]
Dependent variable: lnProd				
lnEmp	−0.631***	−0.699***	−0.613***	−0.618***
	[0.015]	[0.015]	[0.015]	[0.015]
lnWage_lag	1.510***	1.313***	1.569***	1.643***
	[0.082]	[0.078]	[0.081]	[0.080]
lnTrade	0.096***	0.090***	0.099***	0.102***
	[0.008]	[0.008]	[0.008]	[0.008]
GVC	−0.890**		−0.651***	
	[0.390]		[0.055]	
PVC		0.904**		0.433***
		[0.371]		[0.052]
PRVC		2.932***		−0.406***
		[0.391]		[0.031]
N	1541	1541	1760	1760
R^2 (*lnWage_lag*)	0.81	0.81	0.8	0.8
R^2 (*lnEmp*)	0.82	0.85	0.81	0.81
R^2 (*lnProd*)	0.64	0.67	0.61	0.61

Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Industry, province and time dummies included in all specifications, SURE regressions.
Source: own compilation.

Table A.5
Estimation of wages, employment and labour production; added covariate: lagged R&D.

	Forward linkages		Backward linkages	
	(1)	(2)	(3)	(4)
Dependent variable: lnWage				
ln_RD_lag	0.051***	0.052***	0.037***	0.034***
	[0.008]	[0.008]	[0.007]	[0.007]
lnEmp	0.019*	0.025**	0.045***	0.050***
	[0.011]	[0.012]	[0.010]	[0.010]
lnProd	0.066***	0.070***	0.052***	0.054***
	[0.010]	[0.012]	[0.010]	[0.010]
lnTrade	−0.006	−0.006	−0.009***	−0.009***
	[0.004]	[0.004]	[0.003]	[0.003]
GVC	0.143		0.028	
	[0.169]		[0.018]	
PVC		−0.151		−0.044**
		[0.170]		[0.022]
PRVC		−0.249		0.030*
		[0.181]		[0.016]
Dependent variable: lnEmp				
ln_RD_lag	0.449***	0.361***	0.430***	0.405***
	[0.024]	[0.024]	[0.024]	[0.022]
lnWage	0.281*	0.337**	0.737***	0.739***
	[0.170]	[0.162]	[0.162]	[0.153]
lnProd	−0.277***	−0.479***	−0.433***	−0.503***
	[0.040]	[0.041]	[0.038]	[0.036]
lnTrade	0.049***	0.056***	0.058***	0.067***
	[0.014]	[0.013]	[0.014]	[0.013]
GVC	0.156		−0.159**	
	[0.658]		[0.072]	
PVC		0.201		0.420***
		[0.627]		[0.083]
PRVC		2.009***		−0.552***
		[0.665]		[0.057]
Dependent variable: lnProd				
ln_RD_lag	0.032	0.037	0.130***	0.176***
	[0.033]	[0.030]	[0.030]	[0.029]
lnEmp	−0.313***	−0.491***	−0.436***	−0.549***
	[0.046]	[0.042]	[0.038]	[0.039]
lnWage	1.129***	0.980***	0.855***	0.858***
	[0.178]	[0.161]	[0.162]	[0.159]
lnTrade	0.063***	0.065***	0.070***	0.074***
	[0.015]	[0.013]	[0.014]	[0.013]
GVC	−1.05		−0.286***	
	[0.698]		[0.072]	
PVC		1.107*		0.402***

(*continued on next page*)

Table A.5 (*continued*)

	Forward linkages		Backward linkages	
	(1)	(2)	(3)	(4)
		[0.633]		[0.087]
PRVC		3.291***		−0.468***
		[0.663]		[0.061]
N	519	519	619	619
R^2 (*lnWage*)	0.85	0.85	0.85	0.85
R^2 (*lnEmp*)	0.88	0.88	0.86	0.88
R^2 (*lnProd*)	0.58	0.64	0.6	0.61

Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Industry, province and time dummies included in all specifications, SURE regressions.
Source: own compilation.

Table A.6
Estimation of wages, employment and labour production; sector heterogeneity.

	Forward linkages		Backward linkages	
	(1)	(2)	(3)	(4)
Dependent variable: lnWage				
lnEmp	0.105	0.099	0.100	0.099
	Significant	Significant	Significant	Significant
lnProd	0.138	0.131	0.127	0.126
	Significant	Significant	Significant	Significant
lnTrade	−0.005	−0.003	−0.006	−0.006
	Significant		Significant	Significant
GVC	−0.004		0.046	
			Significant	
PVC		0.016		−0.021
PRVC		−0.094		0.024
				Significant
Dependent variable: lnEmp				
lnWage	1.972	1.561	1.998	1.964
	Significant	Significant	Significant	Significant
lnProd	−1.049	−1.059	−0.975	−0.973
	Significant	Significant	Significant	Significant
lnTrade	0.138	0.121	0.146	0.150
	Significant	Significant	Significant	Significant
GVC	−1.007		−0.800	
	Significant		Significant	
PVC		1.052		0.554
		Significant		Significant
PRVC		3.730		−0.459
		Significant		Significant
Dependent variable: lnProd				
lnEmp	−0.636	−0.701	−0.618	−0.620
	Significant	Significant	Significant	Significant
lnWage	1.575	1.355	1.603	1.589
	Significant	Significant	Significant	Significant
lnTrade	0.096	0.090	0.099	0.103
	Significant	Significant	Significant	Significant
GVC	−1.071		−0.651	
	Significant		Significant	
PVC		1.068		0.395
		Significant		Significant
PRVC		3.056		−0.370
		Significant		Significant

Notes: Industry, province and time dummies included in all specifications, SURE regressions.
The results correspond to the average values of the relevant variable's coefficients in 25 regressions (excluding sectors one at a time, which means there are 24 sectors in each regression). 'Significant' means the value of the variable is significant in most regressions.
Source: own compilation.

Table A.7
Estimation of wages, employment and labour production; province heterogeneity.

	Forward linkages (1)	(2)	Backward linkages (3)	(4)
Dependent variable: lnWage				
lnEmp	0.105 Significant	0.100 Significant	0.100 Significant	0.099 Significant
lnProd	0.139 Significant	0.131 Significant	0.127 Significant	0.126 Significant
lnTrade	−0.005 Significant	−0.003	−0.006 Significant	−0.006 Significant
GVC	−0.005		0.046 Significant	
PVC		0.017		−0.020
PRVC		−0.093		0.024 Significant
Dependent variable: lnEmp				
lnWage	1.971 Significant	1.560 Significant	1.998 Significant	1.963 Significant
lnProd	−1.050 Significant	−1.061 Significant	−0.977 Significant	−0.974 Significant
lnTrade	0.138 Significant	0.121 Significant	0.146 Significant	0.150 Significant
GVC	−1.010 Significant		−0.800 Significant	
PVC		1.054 Significant		0.554 Significant
PRVC		3.735 Significant		−0.461 Significant
Dependent variable: lnProd				
lnEmp	−0.636 Significant	−0.702 Significant	−0.619 Significant	−0.621 Significant
lnWage	1.580 Significant	1.360 Significant	1.607 Significant	1.593 Significant
lnTrade	0.096 Significant	0.090 Significant	0.099 Significant	0.103 Significant
GVC	−1.068 Significant		−0.650 Significant	
PVC		1.063 Significant		0.394 Significant
PRVC		3.053 Significant		−0.371 Significant

Notes: Industry, province and time dummies included in all specifications, SURE regressions.
The results correspond to the average values of the relevant variable's coefficients in 31 regressions (excluding provinces one at a time, which means there are 30 provinces in each regression). 'Significant' means the value of the variable is significant in most regressions.
Source: own compilation.

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