Formerly Assembled, But Now Designed in China?
Assessing the Domestic Value-Added of Activities in Gross Exports

Quanrun Chen[a], Yuning Gao[b], Jiansuo Pei[a], Gaaitzen de Vries[a,c], Fei Wang[a]

[a] University of International Business and Economics, Beijing

[b] Tsinghua University, Beijing

[c] University of Groningen, Groningen

Abstract

China has managed to increase the domestic value added content of its exports in recent years. But what is the nature of the global value chain activities that it performs? This paper measures the value added of China's activities embodied in its exports. We combine information on the activities of workers by industry and across China's 31 provinces from population censuses, with newly estimated inter-provincial input-output tables using value-added tax transactions data for 2002 and 2012. Our findings suggest the increase in China's domestic value-added in exports arises from an expansion of fabrication activities. This aggregate trend is driven by provinces like Guangdong, Jiangsu, and Zhejiang. Richer provinces such as Beijing, Tianjin, and Shanghai increasingly specialize in R&D and sales and marketing activities.

Keywords: China; Domestic value-added in exports; Activities; International trade

JEL: F14, F60, O19, R11

Acknowledgements

We thank Bo Meng, Heiwai Tang, Zhi Wang, Viktor Stolzenburg, and conference participants at the Pre-conference of the China Development Forum (Beijing, March 2018) for helpful comments and discussions.

1. Introduction

During past decades, the development of global production networks has allowed firms to rely less on domestic inputs for products they sell on the world market. As a result, a common pattern across countries has emerged, whereby the domestic content of exports declines (Johnson and Noguera, 2017). This pattern is observed for almost all developed and developing countries from the 1970s onwards (Johnson and Noguera, 2017).

China defied this declining trend in the domestic content of exports. That is, China's domestic value added content in exports increased during the 2000s (Koopman et al. 2012; Kee and Tang, 2016).[1] What underlies the increase in China's domestic value added in gross exports?

The aim of this paper is to analyze China's domestic value added from activities in exports. Current studies trace the international flows of domestic value added in exports, but do not provide information on the nature of the activities that are performed. Yet, this is crucial in appraising the potential for development under global value chain integration (de Vries et al. 2018). That is, activities differ in their potential for productivity growth as well as in generating knowledge and other spillovers.

The iconic example that motivates our approach is the iPhone. On the back of the iPhone it reads 'designed by Apple in California, assembled in China'. It reflects the global configuration of production whereby activities are undertaken at different locations. China's exports of iPhones thus embody domestic value added from its fabrication activities. But this case study may not be representative of China's electronics exports. Indeed, China's export of smartphones is a diverse bundle of brands and models, including smartphones from China's own brand manufacturers, such as Huawei and Xiaomi. These firms do design, marketing, and after-sales services activities. In a nutshell, does the increase in China's domestic value added during the 2000s reflect a movement towards higher value-adding activities?

[1] Johnson and Noguera (2017) document a long run decline in the domestic value added in exports for the majority of developed and developing countries. Their analysis reveals that during the 1970s to 2010s, China's domestic content in exports fell. We focus on the period from 2002 to 2012 for which scholars document an increase in the domestic value added of China's exports (Koopman et al. 2012; Kee and Tang, 2016).

In our empirical analysis, we will distinguish between four possible business activities: R&D, fabrication, marketing, and other support services. We measure the contribution of an activity as the wage income of workers that perform it, based on their occupation. To implement the approach, we create a rich new dataset. It includes detailed data on the occupations of workers in forty-two industries in thirty-one provinces of China from the 2000 and 2010 population census. It is combined with information on inter-industry and inter-provincial flows of intermediate inputs build up from value-added tax invoice data.

We first document China's domestic value added in exports. Using the inter-provincial input-output tables, we find that the domestic content increased from 70 to 72 percent between 2002 and 2012. This increase is consistent with findings in previous studies (Koopman et al. 2012; Kee and Tang, 2016).[2] Domestic value added in exports (hereafter VAX_D)[3] is the sum of income accruing to the production factors capital and labor. We identify domestic value added exports of a particular function by the labor income of workers that perform the function (de Vries et al. 2018). This allows us to examine the nature of activities that are performed. For China, we find that the increase in VAX_D arises from an expansion of fabrication activities.

The finding appears to contrast with findings in the international business literature and in firm case studies that indicate a strong expansion of knowledge-intensive activities in the pre-fabrication (R&D, innovation, engineering, etcera) and the post-fabrication stage (sales and marketing, logistics, etcetera) in China.[4] We show it can be reconciled by analyzing the sub-national domestic value added of activities in exports. China's economy and workforce is vast and there are huge differences in levels of economic development and global value chain specialization patterns across China's provinces (Meng et al. 2013). For example, income per capita in Shanghai (the richest province in China) is almost six times higher compared to Guizhou (the poorest province).[5] Many headquarter locations are in cities like Beijing and

[2] Although there is broad agreement among scholars about the rising trend in the domestic content of exports by China, there are differences in estimates of the domestic content of exports discussed in section 2.

[3] We follow notation introduced by Los and Timmer (2018). VAX_D is domestic value added embodied in exports as in Koopman et al. (2014).

[4] See e.g. Lewin et al. (2009), Frederick and Gereffi (2011), Assche and van Biesebroeck (2018). Further discussed in section 2.

[5] Provincial GDP per capita in 2010 in current prices is 76,074 yuan in Shanghai and 13,119 yuan in Guizhou (NBS SY, 2011).

Shanghai. The aggregate increase in VAX_D from fabrication activities is driven by provinces like Guangdong, Jiangsu, and Zhejiang. But richer provinces like Beijing, Tianjin, and Shanghai have started to specialize in R&D and sales and marketing activities.

The set-up of our study is related to studies of the factor content of trade as in Reimer (2006) and Trefler and Zhu (2010) and factor distributions in global value chains as in Timmer et al. (2014). Rather than analyzing different types of factor inputs such as capital and labor distinguished by educational attainment levels, we focus on the type of activity that workers carry out as in de Vries et al. (2018). Activities do not correspond clearly to a particular sector or industry. For example, in many statistical systems, firms are classified based on their primary business activity. But firms often perform and combine many activities in-house including both production and various types of support services, making it often hard to establish their primary activity. Studying the sector distribution of value-added in trade as in Johnson and Noguera (2012) and modelled by Bridgman (2012) will therefore not reveal functional specialization patterns.

Studying the subnational domestic value added from activities in exports is important as it helps to reconcile findings in the international trade literature with studies in international business. Regional assets interact with local institutions. Together it determines the potential for economic upgrading. Much depends on the type of activities carried out as they differ in their potential for productivity growth as well as in generation of knowledge and other spillovers. Activities also differ in their likelihood to be affected by relocation: functional unbundling has to be studied in conjunction with geographic unbundling. For example, agglomeration forces are likely to induce spatial inertia in research and development activities, yet are much less relevant for assembly, testing or packaging activities. Better understanding of the viscidity of current activities in a region is therefore also key in policy making (Baldwin and Evenett, 2012).

The remainder of this paper is as follows. Section 2 provides a selected review of the literature on the domestic content of exports in China and international business and case studies of functional upgrading by Chinese firms. Section 3 describes the collection and approach for constructing a unique data set to examine functional specialization patterns in China. Section 4 outlines the measurement of domestic value added in exports by business function. Section 5 first documents the increase in China's VAX_D, examines changes in the functional specialization shares in VAX_D, and finally examines functional specialization patterns across China's provinces. Section 6 concludes.

2. Domestic value added in exports: a selected review of the literature

We first review the literature on China's domestic value-added in exports in section 2.1. There is mounting evidence that the domestic content in exports increased since the 2000s. So far, this strand of literature has not informed on the nature of activities carried out in production. We then review the international business literature and case studies on functional upgrading in China in section 2.2. These studies suggest that China is undertaking an increasing range of knowledge-intensive activities in production networks. It suggests that the aggregate increase in domestic value-added in exports originates from functional upgrading. This hypothesis is examined in the sections thereafter.

2.1 China's domestic value added in gross exports

Due to international production fragmentation, what countries export can be very different from what they actually contribute to the production process. To capture this, Hummels et al. (2001) proposed a new measure of vertical specialization in trade: the share of domestic value added (VAX-D) in gross exports.[6] This share is one when all activities needed to produce the exported good are performed within the exporting country. Put otherwise, all stages of production take place domestically. The share is declining in the amount of intermediates imported by the country in any stage of production. A country with a low share is thus said to be vertically specialized in trade, carrying out a limited number of production stages. Using input-output tables for fourteen countries compiled by the OECD, they found that the domestic value added share in exports (VAX-D ratio) decreased for every country (but Japan) between 1970 and 1990. China was not included in their analysis.

[6] In fact, Hummels et al. (2001) derived the import content of exports, and referred to these as VS. Koopman et al. (2014) defined domestic value added in exports and showed that it is equal to gross exports minus VS (see also Los et al., 2016).

In an influential study of China’s exports, Koopman et al. (2012) argued for the need for detailed data to measure specialization in case processing trade is pervasive. Export processing firms import parts and components, typically with tariff exemptions and other tax preferences, and, after assembling, export the finished products. Koopman et al. (2012) generalize Hummels et al. (2001) to take account of the much higher use of imported inputs by processing relative to standard exporters. Overall, they found that VAX-D in China’s manufacturing exports was about 50% in 1997 and 2002, increasing to 60% in 2007. Export from sectors that are typically labelled as relatively sophisticated such as computers and telecommunication equipment had a particularly low ratio (45% or less in 2007). It confirmed casual observations that what China was contributing to production is very different from what they export. In addition, these findings led to a more general recognition of the importance to account for heterogeneity across firms in import use when analyzing specialization in trade.

Kee and Tang (2016) embrace firm heterogeneity by measuring China’s VAX_D as a weighted average of the firms’ VAX_Ds. Their VAX_D estimates confirm that China’s VAX_D has been rising. They find that China’s VAX_D increased from 65% in 2000 to 70% in 2007. This is higher than what is reported by Koopman et al. (2012). The Input-Output tables that Koopman et al. (2012) used are estimated based on samples of large firms. Typically, larger firms have a higher import-to-sales ratio and therefore a lower VAX_D compared to small firms. Kee and Tang (2016) show that if they measure VAX_D as a weighted average of only VAX_Ds of the large firms’, the estimates are not different from Koopman et al. (2012).

Meng et al. (2017) measure VAX_D across China’s provinces using inter-provincial input-output tables for 1997 and 2007. They find that China’s inland provinces have tended to produce more value added by joining the domestic portion of coastal regions’ global supply chains instead of relying on increasing its direct exports to the world market.

What underlies the increase in China’s VAX_D? Kee and Tang (2016) find that it is mainly driven by individual processing exporters substituting domestic for imported materials, both in terms of volume and varieties. This suggests that the increase in VAX_D is driven by an expansion of domestic fabrication activities.

This aggregate pattern, however, may obscure important differences across China’s provinces. Indeed, Meng et al. (2013, 2017) point out that with falling domestic transport and ICT costs, firms have been outsourcing part of their production to other provinces. This allows them to focus more on their core competencies, namely pre- and post-fabrication activities. We will examine the domestic value-added of activities in gross exports for China and the distribution of domestic activities across its provinces.

2.2 Activities in Global Value Chains

One way to examine a shift towards more value-adding activities is to study the integration or the move into more sophisticated business functions or skill-intensive activities in GVCs (Humphrey and Schmitz, 2002). For example, the shift from doing mainly assembly activities to own-equipment manufacturing to ultimately own-brand manufacturing (Gereffi, 1999). This will be reflected in changes in the share of domestic value-added from activities in exports.

Until recently, the offshoring of knowledge-intensive activities by MNEs from high-income countries was pioneered by only a few companies and was primarily between a limited set of high-income countries. But Dossani and Kenney (2007) argue that offshoring of knowledge intensive services has become a routine business decision. MNEs increasingly resort to offshoring knowledge-intensive activities in order to cope with the need to integrate dispersed sources of knowledge and implement a faster and cheaper innovation process (Castellani and Pieri, 2013). In particular, Dossani and Kenney (2007) argue that since 2004 we have entered a new phase in which high-skilled services jobs are offshored to emerging countries. Cheap but educated workforces in China and other emerging countries provide enormous opportunities for firms to offshore entire functions such as marketing, human resources and customer services. High-technology US startups nowadays establish offshore subsidiaries to undertake for example high-end semiconductor design activities and software algorithm development (Dixit, 2007; Shah, 2005). Indeed, there is now a rich literature that studies the expansion of knowledge activities in emerging countries (Dossani and Kenney 2007; Di Gregorio et al. 2009; Lewin et al. 2009; Nieto and Rodríguez 2011; Castellani et al. 2013, Kenney et al. 2009).

There are also insightful case studies that examine the movement into higher value adding activities in China. Frederick and Gereffi (2011) compare the apparel industry in China to that in Mexico. They find that growing domestic apparel demand and an integrated Asian production network allowed Chinese apparel firms to functionally upgrade in GVCs. The state provided active support by investing in textile-processing equipment and logistics. This contrasts to Mexican apparel firms whose exports heavily rely on the US consumer market and which have not developed a production network in Central America.

Assche and van Biesebroeck (2018) measure functional upgrading in China by analyzing changes in the relative prevalence of two types of export processing trade, namely pure-assembly and import-assembly. In contrast to pure-assembly, with import-assembly the export processing firm imports inputs of its own accord and retains control over their use during the production process. This requires the selection and governance of relations with suppliers as they need to manage inventories and logistics as well as being responsible for quality. Assche and van Biesebroeck (2018) find that import-assembly export processing firms have become more prevalent both overall and within product categories since 2000.

These studies suggest an upgrading in functional capabilities. We provide a complementary macro-economic perspective and examine this hypothesis in section 5. First we discuss data and methods.

3. Data

Section 3.1 describes the occupations data to measure labor income from business functions by province-industry pairs. Section 3.2 discusses the estimation of inter-provincial input-output tables based on firm level transactions data. Both datasets are combined in the sections hereafter to examine the domestic value added of activities in exports between 2002 and 2012.

3.1 Estimating domestic value added in activities

Our identification strategy follows de Vries et al. (2018) and infers value added by business function from data on the occupational structure of the work force. Occupation data is mapped into functions. For guidance on the mapping we used the list of business functions proposed by Sturgeon and Gereffi (2009), which itself is derived from a list of generic business functions first proposed by Porter (1985). A well-known distinction is between fabrication and headquarter activities (Markusen, 2002). We start from that distinction, further splitting headquarter into R&D and technology development (abbreviated R&D), sales and distribution (Marketing), and other support activities (Other support). In choosing the number of functions we have to strike a balance between the level of detail and maintaining comparability across provinces and over time.

Our primary data sources for occupations data are the 2000 and 2010 China Population Census. We collect and harmonize occupations data for 31 Chinese provinces (see Appendix Table A1 for the provinces distinguished) and in each of these provinces distinguish 42 sectors (see Appendix Table A2 for the sectors distinguished). We use the 0.1 percent samples, with approximately 1.3 million (1.2 million) observations for 2010 (2000).[7] Business function employment shares are estimated at an aggregate 9 sector level and shares are assumed equal for more disaggregated sub-sectors (see the final column in Appendix Table A2). The procedure to estimate more aggregated shares is a common and more robust approach when using micro data (see e.g. O'Mahony and Timmer, 2008).

The population census provides information on occupational employment cross-classified by industry and province. To measure wages by occupation, we use the 2002 and 2013 China Household Income Project (CHIP) survey. These surveys provide relative wages by broad (1 digit) occupation group and we assume the relative wage can be used for more disaggregated occupations within each broad occupational group. We combine the business function shares with labor shares in each province-industry, which are available at the detailed 42 sector level (further discussed in section 3.2).[8]

We map occupations to business functions (see appendix Table A3 for the concordance). This new and detailed dataset on activities at the province-industry level is combined with information on inter-industry and inter-provincial trade flows from Inter-Provincial Input-Output Tables (IPIOs) for 2002 and 2012, described next.

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[7] Sampling weights are not provided. This may introduce bias in the business function shares. From NBS, China's statistical office, we obtained industry by occupation data for China (not by province), which NBS tabulated on the basis of 10 percent samples of the population censuses 2000 and 2010. We compared the business function shares from the data provided to NBS to the shares based on the 0.1 percent sample. The business function shares for China as a whole are very similar and also the correlation at the industry-business function level is high, ranging from 0.73 (employment share in other support activities by industry in 2010) to 0.995 (employment share in marketing activities by industry in 2000).

[8] Note that we use the business function employment shares from the 2000 population census in combination with relative wages from the 2002 CHIP survey and the 2002 Inter-Provincial Input-Output (IPIO) table. We use the 2010 population census in combination with the relative wages from the 2013 CHIP survey and the 2012 IPIO.

3.2 New Inter-Provincial Input-Output tables for China

Our approach to estimate inter-provincial input-output tables consists of three steps. In a first step, we use as initial tables the inter-provincial input-output tables from Zhang and Qi (2012).[9] Second, we adjust the row and column totals as well as the GDP factor income shares using the survey-based provincial input-output tables provided by China's statistical bureau. We benchmark China's GDP in the IPIO to that published in the national accounts. Third, we improve upon the estimated trade flows between industries and provinces (the internal structure of the IPIOs) using aggregated firm-level transactions data. We discuss each step in turn.

3.2.1 Initial estimates of inter-provincial input-output tables

Inter-provincial input-output (IPIO) tables for 2002 and 2012 have been compiled by Zhang and Qi (2012). These IPIOs show how the output of a given industry in a given province is divided between final consumption and intermediate use by all other province-industries in China and the rest of the world. Provinces are an administrative division, which does not align well with the regional spread of economic activities in China. But this is the type of data we have to work with.

The IPIO provides data on $m_i = 42$ industries and $m_p = 31$ provinces, and a column with exports to `the rest of the world'.[10] The basic structure of the IPIO for a given year is given in Figure 1. The units of observations are the $m_i m_p = 1{,}302$ unique province-industry pairs. The $m_i m_p \; x \; m_i m_p$ matrix **Z** records the flows of output for intermediate use between industries. The entry in row *a* and column *b* equals the use (in Yuan) by industry-province *b* of intermediate inputs provided by *a*. The $m_i m_p \; x \; m_p$ matrix **F** contains for each province-industry the output for final use in every province plus a $m_i m_p \; x \; 1$ vector **e** with exports to the rest of the world. Gross output for each province-industry pair is given by the $m_i m_p \; x \; 1$ supply vector **s**. Because total supply is by necessity equal to total intermediate and final use, the following equation has to hold:

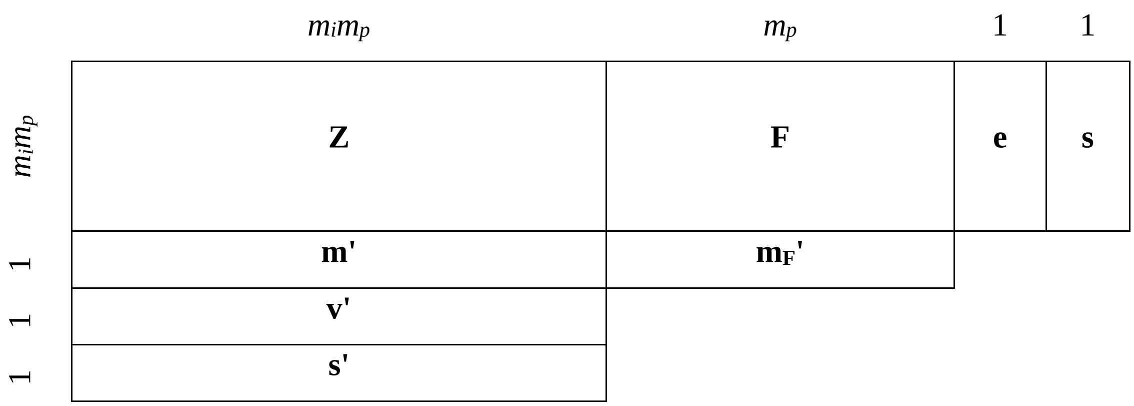
[9] China's multi-regional input-output table with eight regions for 2002 is from Zhang and Qi (2012). The authors provided us with a new inter-provincial input-output table for 2012.

[10] The IPIO for 2002 provides data on 29 industries and 30 provinces instead of the 42 industries and 31 provinces in the IPIO for 2012. The lower number of industries is because the services industries in the IPIO 2012 are collapsed into a single services industry in the IPIO 2002. The lower number of provinces in the IPIO for 2002 is because Tibet did not compile an input-output table in 2002. We adjust both dimensions in the 2002 IPIO, further described below.

$$\mathbf{s} = \mathbf{Z1}_{m_i m_p} + (\mathbf{F}+\mathbf{e})\mathbf{1}_{m_i m_p}, \qquad (1)$$

where **1** is a vector of ones and the subscript denotes its dimension. In other words, if we sum up over the elements of **Z** and **F** in a given row, then we arrive at the corresponding value of **s**. Similarly, if we sum up over a column of **Z** to obtain the total worth of intermediate inputs used in a given province-industry and include its imports of intermediates (an element of the 1 x $m_i m_c$ vector **m**`) and value added (an element of the 1 $x$ $m_i m_p$ vector **v**`) we also arrive at total output of this province-industry.

Figure 1. Structure of the inter-provincial input-output table



Notes: The data consists of m_i industries, and m_p provinces. **Z** is the matrix of intermediate use, **F** is the matrix of final demand, **m** is the vector of imports of intermediate inputs, $\mathbf{m_F}$ the vector of imports of final goods and services, **e** is the vector of exports, **s** is the vector of gross output, and **v** is the vector of value added.

We use these IPIOs as initial estimates and provide one important adjustment and one important improvement. First the adjustment. The initial IPIOs are product by product tables, while our data on business activities are by industry. Also, we would like to benchmark the tables to national accounts data that provide value added by industry. We therefore replace the vectors **v** and **s** by industry data from benchmarked provincial supply and use tables. This is described in the next subsection.

The improvement is with respect to the intermediate input transactions in matrix **Z**. These transactions are estimated in the initial IPIOs using gravity models complemented by transportation data (Zhang and Qi, 2012). The accuracy of these estimates can be questioned, and we will use detailed tax-invoice transactions data to improve measurement of intermediate input flows. This is described in subsection 3.2.3.

The revised IPIOs that we develop here are an improvement upon existing approaches. It is not without limitations however. In particular, section 2 discussed the importance of allowing for firm heterogeneity when measuring the domestic value added in exports. Our province-industry analysis aggregates over heterogeneous firms and this may bias the results. The direction of the bias is not clear a priori. It could be overestimated for some province-industry pairs and underestimated for others. For example, if processing trade is pervasive in a particular province-industry, the domestic value added in exports is likely to be over-estimated and vice versa.

3.2.2 Adjustments to the initial IPIO

The adjustment of the initial IPIO is to create an industry-by-industry IPIO consistent with China's GDP as reported in the national accounts.

First, we transformed the provincial IOTs for 2002 and 2012 to product-by-industry SUTs using the 'product technology' assumption (Miller and Blair, 2009). Among others, this results in a vector of province-industry value added. A well-known issue about China's statistics is that provincial GDP does not sum to China's GDP reported in national accounts. The values we obtain for value added by industry in each of the $m_p = 31$ provinces are made consistent to that reported in the national accounts. The adjustment factor x is as follows:

$$x = \frac{NA}{\sum_i \sum_p v_{ip}}, \quad (2)$$

where NA is GDP reported in the national accounts, v_{ip} the value added of industry i in province p, obtained from the provincial SUTs. The value added and gross outputs are adjusted by the same proportion x.[11] We do this for the years 2002 and 2012 using the national accounts data reported in the China Statistical Yearbook 2017 (NBS SY, 2017).

Similarly, values of final expenditure for 2002 and 2012 are made consistent to the national accounts by using the adjustment factor r:

[11] We also adjust gross output by the same proportion, this keeps the value added to gross output ratio from the provincial SUTs intact. This is relevant for measuring the domestic value-added in exports (see next section).

$$r = \frac{NA - ne}{\sum_p f_p}, \quad (3)$$

where *ne* are the net exports from China's national accounts, and f_p the final expenditure (excluding net exports) of province *p* in the provincial SUTs. The adjustment factor excludes net exports. This is because China does not include imports and exports that do not change ownership in its national accounts (consistent with the SNA 2008 guidelines). The regional input-output data, however, include imports and exports that do not change ownership. Hence the exports and imports by pure-assembly export-processing firms are included. In our analysis we prefer to include this type of trade and therefore do not adjust the total exports and imports reported in the provincial SUTs.

After these adjustments, we replace the vectors **v** and **s** (adjusted by the *x* factor) and the matrix **F** (adjusted by the factor *r)* in the initial IPIO. To achieve consistency between row and columns sums, the IPIO is then updated using a bi-proportional updating method for IOTs known as the Generalized RAS-technique (Miller and Blair, 2009).

Labor shares in value added, which we split by business activity using the shares derived in section 3.1, are the labor compensation by industry as provided in the provincial input-output tables. Before the first Economic Census in 2004, the income of self-employed and their employees are included in labor compensation but not thereafter (NBS, 2003). While profits related to owners (informal entrepreneurs) should be part of gross operating surplus, we consider the labor compensation in the input-output tables before 2004 closest to the definition of labor compensation in value added. After the economic census, two changes in the income GDP accounting method introduce a break in the labor share time series by industry (Bai and Qian, 2010). First, profits of state-owned and collective-owned farms are included in labor compensation, introducing an upward break in the agricultural labor shares. Second, income of self-employed owners is subsequently included in gross operating surplus. We use the adjustment factors for both changes at the province-sector level in Bai and Qian (2010) to arrive at consistent time series following the definition of labor shares before the 2004 Economic Census.

3.2.3 Transaction data at the firm level

Declarations of deliveries by business customers are reported to the China State Administration of Taxation. It records for every VAT-registered business the annual value of its deliveries to any other VAT affiliate, as long as this amount is greater than or equal to 500 million yuan per year for merchandise producers or taxable labor service vendors or greater or equal to 800 million yuan for other businesses (general tax payers). This annual value of sales from firm *i* to firm *j* is called a transaction. This transaction is not split between the potentially multiple goods and services traded between firms *i* and *j*. It only represents the total value of goods and services traded between those two firms. However, we may observe bilateral trade between those two firms. In this case, we observe both the transaction between *i* (as a seller) and *j* (as a buyer) and its reverse transaction between *j* (as a seller) and *i* (as a buyer). If the two firms are registered in different provinces, it is recorded as inter-provincial trade. If they are located in the same province, it is intra-provincial trade.

This dataset therefore provides a good coverage of the trade linkages between Chinese firms. The China State Tax Administration office provides us these linkages at a detailed industry and province level from 2003 onwards using the firm transactions data. The dataset is most complete for firms producing agricultural and manufacturing products, while the coverage for service firms is better for later years. [12] It enables us to characterize the local production network.

The province-industry to province-industry transaction data can be viewed as a type of input-output matrix where each row and each column is a province-industry. In that respect, it is therefore a very suitable tool for analyzing the organization of production chains at the national level. However, it departs from input-output data in three ways. First, we have no information of what is traded between two firms. We are therefore not able to distinguish between intermediate inputs and investment inputs. Second, the manner in which wholesale and retail trade intermediaries are recorded is fundamentally different from that of standard IOTs. In standard IOTs, the contribution of the wholesalers and retailers to the economy and their intermediate deliveries to other sectors is measured in terms of the value added generated by wholesalers and retailers. In our transaction data, we observe gross transactions to or from trade intermediaries. The contribution of wholesalers and retailers in the network is therefore much larger than in

[12] From 2012 onwards, services firms from some sectors and regions started to pay VAT and all sectors and provinces are covered since 2017. Before that, services firms paid business taxes.

standard IOTs. Third, there is no intra-firm trade in our dataset.[13]

Using VAT invoice data to measure trade flows carries some well-known limitations (Keen and Smith, 2006). For example, there can be invalid or lost invoices, fake invoices, fraud, and small transaction values are typically not included. These issues affect the quality of the data, although Xing et al. (2015) argue that the centralized and rigorous administrative system in China help to improve the reliability of the data.

Previous attempts to estimate inter-provincial transactions proofed to be very difficult, simply because there is no statistical agency that records transactions between provinces like customs records transactions between nations. The firm level VAT transaction data that we use is consistent with the input-output table from China's national statistics while at the same time we are able to use detail to reveal domestic value chains. By using the VAT data, we are able to improve the inter-regional transaction matrices of the IPIO through the interconnection of aggregated firm level value chains.

We calculated the industry specific sale structure across provinces for each province based on the aggregated firm-level transaction data. This sale structure matrix is then multiplied by the industry specific total sale of each province, which results in an initial update of the inter-province intermediate delivery matrix **Z** (see figure 1). This matrix is then further balanced by using the RAS procedure.

4. Method

This section proceeds in two steps. First, we trace domestic value added in gross exports (VAX_D).[14] VAX_D contains value that is added by the exporting industry, as well as the value added contributions of other industries that contribute indirectly through the delivery of intermediate inputs. To account for these indirect contributions, one needs to use information from input-output tables in a procedure that was originally developed by Leontief (1949). Second, we follow de Vries et al. (2018) who extend VAX_D by tracing what type of activities

[13] There is no data for the intra-firm trade for general tax payers. However, inside each enterprise group trade is recorded anytime a VAT invoice is issued. Thus this issue may not be that influential. Moreover, along with the improvement of the legal persons' general taxpayer qualification process in recent years, the "headquarters effect" (Xing, Whalley and Li, 2015) caused by the separation of the invoice issuing entities and the actual transaction entities has been weakening, even with the transaction volume structure anomalies that usually occur in Beijing and Shanghai where many firms' headquarters are at.

[14] See Hummels et al. (2001) and Koopman et al. (2014).

contributed to this value added. We write the method here in terms of tracing the domestic value added of activities across Chinese province-industries. The VAX_D of China is defined as the aggregation of VAX_D over all province-industries.

As before, let **e** be a vector of exports (of dimension $m_i m_p$ x 1). Let **A** the $m_i m_p$ x $m_i m_p$ intermediate input coefficient matrix with typical element a_{st} indicating the amount of product *s* used in production of one unit of *t* (see Figure 1, imported intermediate inputs are not included in **A**).[15] We can then derive a vector **y** ($m_i m_p$ x 1) which represents the total gross output needed in each province-industry to produce exports as:

$$\mathbf{y} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{e}, \qquad (3)$$

where **I** is a $m_i m_p$ x $m_i m_p$ identity matrix with ones on the diagonal and zeros elsewhere. $(\mathbf{I} - \mathbf{A})^{-1}$ is the well-known Leontief inverse matrix which ensures that all output related to exports, direct and indirect, are taken into account.

Let vector **d** ($m_i m_p$ x 1) be the amount of domestic value added needed for exports. It can be derived by pre-multiplying **y** as given in equation (3):

$$\mathbf{d} = \mathbf{V}\mathbf{y}, \qquad (4)$$

where **V** is the matrix ($m_i m_p$ x $m_i m_p$) with diagonal element v_{gg} representing the value added to gross output ratios for industries *i* in province *p* and zeroes on the off-diagonal elements. Note that vector **d** contains value added generated in industries that export as well as in non-exporting industries through the delivery of intermediate inputs.

For the purpose of this paper, this approach is extended as follows. Let **B** be a matrix of dimension *b* x $m_i m_p$, where *b* is the number of different business functions. A typical element of this matrix, b_{bip}, denotes the income of all workers performing business function *b* in industry *i* of province *p*, expressed as a share of value added in *i* of province *p*. Then

$$\mathbf{G} = \mathbf{B}\,\mathrm{diag}(\mathbf{d}), \qquad (5)$$

where matix **G** is of dimension *b x* $m_i m_p$ and the typical element g_{bip} represents value added by function *b* in industry *i* of province *p* in gross exports.

[15] $\mathbf{A} = \mathbf{Z} * \mathrm{diag}(\mathbf{s})^{-\mathbf{1}}$. In the set-up of models of value added trade, each product is associated with an industry.

Substituting (5) and (4) in (3), we derive

$$\mathbf{G} = \mathbf{B}\mathbf{V}(\mathbf{I} - \mathbf{A})^{-1}\text{diag}(\mathbf{e}). \qquad (6)$$

This is our key equation to measure the domestic value added by function in a provinces' exports. China's domestic value added from activities in exports is then given by

$$VAX\_D_b = \sum_i \sum_p \mathbf{G} \,/\, \sum_i \sum_p \mathbf{e} \qquad (7)$$

It should be noted that the value added by a function is measured by the costs of workers that carry it out. The sum across all functions (all elements of **G**) is thus equal to the overall wage bill in gross exports. We assume factor price equalization such that differences in labor productivity are reflected in wages.

The domestic value-added from activities in gross exports is labor income that accrues to the provinces' workers. This is our preferred unit of analysis because workers live, work and participate in a geographical area. Capital income, which is the remainder when wages are subtracted from value added, is analyzed separately.[16]

4.2 Measuring functional specialization in trade

The standard tool to analyze specialization patterns is by means of the Balassa index, after Balassa (1965), which originally refers to the relative trade performance of countries. It compares a country's share in world exports of a particular product group to its share in overall exports. However, a province that looks like a dominant exporter in a particular product may in fact contribute little value to those exports. Koopman et al. (2014) argue therefore that this analysis should be performed on the basis of VAX_D instead. We continue this line of reasoning. As before, let subscript p be a province, and define g_{bp} the domestic value added from business function b in province p's exports. These are calculated according to equation (6) using

[16] One reason is the increasing divergence between the location of the assets (where they are used in production) and the location of their owners. The emergence of global production chains involved sizable flows of cross-border investment, and part of the generated value-added will accrue as capital income to multinational firms. The residence of the ultimate recipients is notoriously hard to track, not least because of the notional relocation of profits for tax accounting purposes (Lipsey, 2010). Analyses of labor income potentially suffer from the same problem due to immigrant and inter-provincial labor flows, but arguably this discrepancy is much smaller. Another reason is that capital assets cannot be straightforwardly allocated to functions, in contrast to workers. For example, a computer can be used in many business functions and we have no information on its particular use apart from the industry that is using it.

appropriation summation. We then define the functional specialization (FS) index for function b in province p as

$$\mathrm{FS}_{bp} = \frac{\left(g_{bp}/\Sigma_b\ g_{bp}\right)}{\Sigma_p\, g_{bp}/\Sigma_p\, \Sigma_b\ g_{bp}}\ . \tag{8}$$

The numerator measures the share of function b in overall functional income from province p that is embodied in exports. The denominator calculates the income share of this function in exports of all Chinese provinces. If the index is above one, the province is said to be specialized in that function.

The FS has a degree of intuitive appeal as a measure of specialization, but should not be straightforwardly interpreted as a measured of (revealed) comparative advantage. This awaits further grounding in models of international trade that include a full structure of input-output linkages across countries.

5. Results

Section 5.1 presents results on the domestic value added content of exports in China and measures the contribution by province to these aggregate trends in domestic value added. Section 5.2 examines changes in the income share from pre-fabrication, fabrication, and post-fabrication activities and provides suggestive evidence of a smile curve. Section 5.3 examines functional specialization in trade across provinces in China.

5.1 China's domestic value-added in gross exports

Table 1 examines domestic value added in gross exports of China. The first row shows the phenomenal increase in nominal gross exports, which increased more than fivefold from 2,783 billion to 14,510 billion yuan between 2002 and 2012. Domestic value added also increased. In fact, it increased at a faster pace compared to gross exports (see row 2). As a consequence, the domestic value added content of China's gross exports increased from 70 percent to 72 percent (row 2 divided by row 1, see the bottom row of Table 1). Our finding is consistent with the literature that has documented an increase in the domestic content of China's exports during this period (Koopman et al. 2012; Kee and Tang, 2016). But what is the nature of the activities that it performs?

Value added by function is shown in rows (4) through (7). Our findings suggest the majority of labor income from exporting is from fabrication activities. In absolute terms, the increase in domestic value-added is mainly from fabrication activities, increasing by more than 2,000 billion yuan between 2002 and 2012. These findings are consistent with Kee and Tang (2016) who have used Chinese firm-level data to document the substitution of domestic for imported intermediates.

Table 1. China's domestic value-added in gross exports

		2002 values	2012 values	2012 minus 2002
Gross exports	**(1)**	**2,782,842**	**14,510,021**	**11,727,180**
Domestic value added exports	(2)	1,953,285	10,449,457	8,496,172
Labor income	(3)	839,319	4,343,822	3,504,504
of which:				
R&D and technology development	*(4)*	*58,740*	*523,138*	*464,399*
Manufacturing and assembly	*(5)*	*588,344*	*2,654,150*	*2,065,806*
Sales and distribution	*(6)*	*152,970*	*992,579*	*839,609*
Other support activities	*(7)*	*39,265*	*173,955*	*134,690*
DVA in exports (row 2/row 1)		0.70	0.72	0.02

Notes: Gross exports of China (shown in row 1) is the sum of foreign and domestic value added exports (row 2). Domestic value added exports is the sum of income for capital and labor. Labor income (3) is split into income from R&D and technology development activities (4), manufacturing and assembly activities (5), sales and distribution activities (6), and other support activities (7), hence (3)=(4)+(5)+(6)+(7). Values are in millions of current Yuan. *Sources*: authors' calculations, see text for data sources.

Table 2 examines the domestic value-added by activity in exports for each of China's 31 provinces. It reports the change in nominal values between 2002 and 2012. The values in the bottom row in Table 2 are equal to those in the final column of Table 1. The top ten contributors for each activity are shown in bold and the ranking is based on the change in domestic value-added from fabrication activities.[17]

The top ten contributors to the increase in domestic value-added are Guangdong, Jiangsu,

[17] For some provinces, e.g. Hainan, we observe a decline in domestic value-added by activity in exports between 2002 and 2012. These changes are mainly driven by a reduction in labor income, whereas capital income substantially increased.

Zhejiang, Shanghai, Beijing, Fujian, Shandong, Hebei, Liaoning and Henan respectively. Most of these provinces are also in the top ten contributors of value added from fabrication activities, but there are some interesting differences, which we will discuss below. The top ten contributors from fabrication activities account are Guangdong, Jiangsu, Zhejiang, Shanghai, Fujian, Shandong, Hebei, Henan, Liaoning, and Shaanxi respectively. Together these ten provinces account for about 75 percent of the increase in domestic value added from fabrication activities in exports. Guangdong alone accounts for almost one third of the change in value added from fabrication activities.

Guangdong is also a top ten contributor to the increase in domestic value-added from pre- and post-fabrication activities. However, a top ten contributor in terms of fabrication activities is not necessarily a top ten contributor for other activities, and vice versa. For example, Henan is a top ten (ranked #8) contributor to the increase in value from fabrication activities. But it is not a top ten contributor in terms of R&D activities (#12) or sales and marketing activities (also ranked #12).

Other interesting cases are Beijing and Tianjin. Beijing is one of the main contributors to the increase in value added from R&D activities (ranked #3) and from sales and marketing activities (#2). However, it is not an important contributor to the increase in fabrication activities (#14). This is also the case for Tianjin. Tianjin is a top ten contributor to the increase in domestic value-added in exports from R&D and sales and marketing activities, but not from fabrication activities.

Hence, the increase in domestic value-added from fabrication activities in exports appears driven by several provinces, most notably Guangdong, Jiangsu, and Zhejiang. Other provinces appear major contributors to the increase in domestic value-added from pre- and post-fabrication activities in exports, most notably Beijing and Tianjin.

Table 2. Change in domestic value-added from activities in exports, by province.

#	Province	Total	RD	FAB	SAL	OTH
1	Guangdong	**907,688**	**81,034**	**593,947**	**188,613**	**44,094**
2	Jiangsu	**547,719**	**85,123**	**326,604**	**116,318**	**19,673**
3	Zhejiang	**296,537**	**43,948**	**155,979**	**79,833**	**16,777**
4	Shanghai	**283,137**	**42,532**	**129,593**	**100,047**	**10,965**
5	Fujian	**205,614**	**25,888**	**128,032**	**44,631**	**7,064**

6	Shandong	**162,641**	**16,971**	**109,632**	**33,755**	2,284
7	Hebei	**130,315**	**11,798**	**96,575**	18,347	**3,595**
8	Henan	**115,180**	9,050	**82,948**	16,977	**6,205**
9	Liaoning	**117,329**	**9,625**	**81,386**	**24,478**	1,841
10	Shaanxi	91,013	7,275	**67,783**	13,760	2,195
11	Guangxi	70,028	3,616	57,144	7,472	1,795
12	Sichuan	82,352	8,959	56,534	14,336	**2,523**
13	Anhui	82,237	9,564	53,631	16,672	2,370
14	Beijing	**259,372**	**72,177**	49,561	**126,772**	**10,862**
15	Hubei	64,665	6,025	47,982	8,491	2,167
16	Hunan	58,111	5,156	41,155	9,926	1,874
17	Xinjiang	45,300	1,639	35,734	7,361	566
18	Shanxi	44,573	3,909	32,453	7,057	1,155
19	Heilongjiang	39,569	3,162	32,066	3,768	573
20	Tianjin	70,898	**16,383**	28,382	**21,005**	**5,129**
21	Inner Mongolia	55,657	8,202	27,651	**18,855**	949
22	Yunnan	23,163	1,095	17,844	3,879	345
23	Huizhou	24,237	3,173	15,769	4,649	645
24	Chongqing	14,946	2,061	6,008	5,863	1,014
25	Tibet	4,886	660	2,829	1,159	238
26	Qinghai	1,499	-126	2,246	-447	-173
27	Jilin	-487	-352	1,728	-1,476	-387
28	Ningxia	-9,740	-408	-8,462	-379	-492
29	Jiangxi	-25,490	654	-16,788	-8,638	-718
30	Gansu	-53,390	-2,867	-42,369	-6,060	-2,094
31	Hainan	-205,054	-11,528	-147,771	-37,413	-8,342
	Total		**464,399**	**2,065,806**	**839,609**	**134,690**

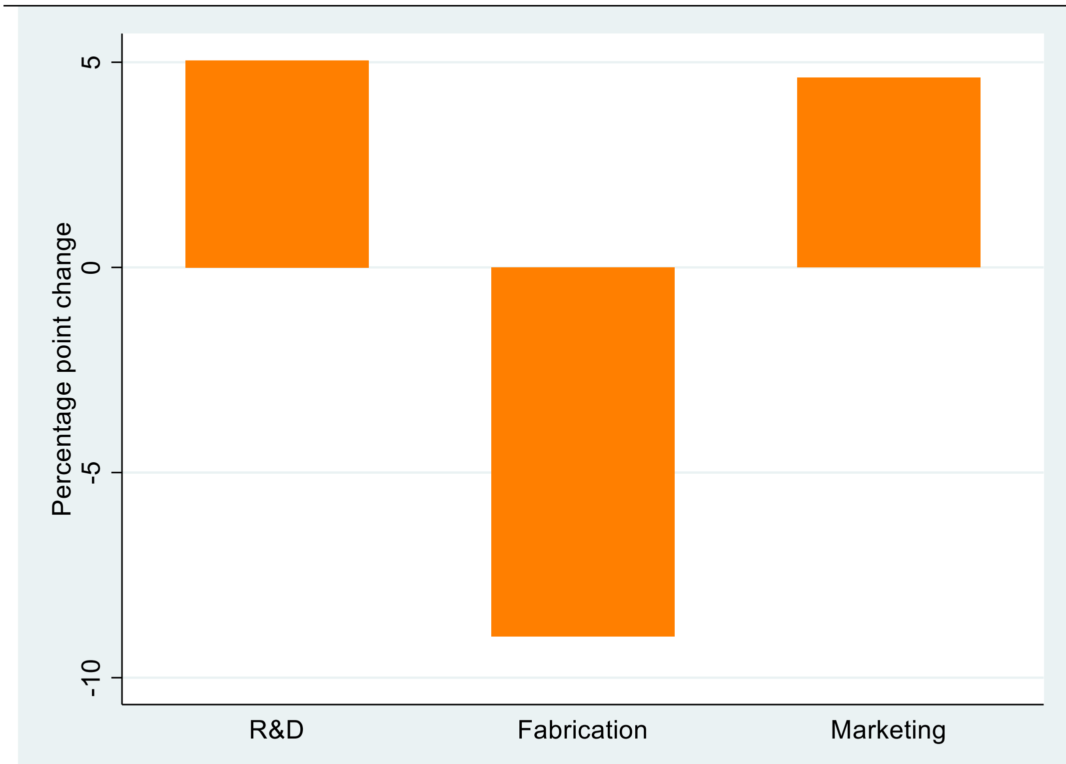
Notes: Nominal values of the change in domestic value added by activity in exports between 2002 and 2012. OTH refers to other support activities; RD to R&D; SAL to sales and marketing; FAB to fabrication activities. Provinces are ranked by change in nominal value of fabrication activities. Numbers in bold are the top ten contributors to domestic value-added in exports for each activity.

5.2 China's smile curve

In the previous section we examined absolute changes in the domestic value-added by activity in exports. Here we documented that the main increase in income originates from fabrication activities. However, the findings documented in Table 1 also suggest the income from pre- and post-fabrication activities increased relatively faster compared to fabrication activities for China as a whole. Income from R&D activities increased almost nine fold (523,138/58,740=8.9), sales and marketing more than six fold, which compares to a fourfold increase in income from fabrication activities. This suggests a change in the relative income from business functions.

Figure 2 shows the change in the income share of a function for China's exports over the period 2002 to 2012 (in percentage points). This is suggestive evidence of a "smile curve", which represents the amount of value that is added to a given product in each stage of production (Mudambi, 2008). When Stan Shih of Acer introduced the concept of the smile curve in the early 1990s he noted that profit margins, productivity levels, and growth opportunities tend to be higher in pre- and post-fabrication activities compared to fabrication activities. Thus, the "smile" signifies that (increases in) value added (per worker) are higher in pre- and post-fabrication relative to fabrication. The value added share of fabrication activities in total exports declined by almost 9 percentage points. In contrast, R&D, and sales and marketing shares increased by 5 and 4.6 percentage points respectively. The observed pattern in Figure 2 suggests a relative shift towards pre- and post-fabrication activities, and away from fabrication.

Figure 2. Changes in functional income share from exporting



Notes: Percentage point change in the distribution of domestic value added in China's exports by function between 2002 and 2012. *Source*: Authors' calculations, see main text.

In Table 3 we show the percentage point change in the income share of a function for China's exports by province over the period 2002 to 2012. Provinces in bold shows a similar 'smile curve' pattern as for China as whole.

For 16 out of 30 provinces we observe a smile curve. Most of these are also the provinces that provide the majority of domestic value added in China's exports (the ordering of provinces is the same as in Table 2). Interestingly, the strength of the smile curve differs across provinces. In addition, for 14 out of 30 provinces we observe a stronger increase in income from fabrication activities compared to pre- and post-fabrication activities. This suggests differences in functional specialization in trade across provinces, to which we turn next.

Table 3. Changes in functional income share from exporting, by province.

#	Province	RD	FAB	SAL
1	**Guangdong**	**4.2**	**-12.6**	**6.6**
2	**Jiangsu**	**8.6**	**-7.8**	**1.2**
3	**Zhejiang**	**3.5**	**-8.3**	**5.5**
4	**Shanghai**	**5.3**	**-23.8**	**20.2**
5	**Fujian**	**2.6**	**-4.3**	**3.8**
6	**Shandong**	**2.7**	**-3.2**	**3.1**
7	Hebei	1.7	1.2	-0.5
8	Henan	-2.0	13.0	-11.4
9	Liaoning	-1.4	5.3	-1.4
10	Shaanxi	0.8	4.3	-3.8
11	Guangxi	-1.3	7.8	-5.4
12	Sichuan	-0.6	11.0	-8.4
13	**Anhui**	**3.6**	**-7.5**	**4.7**
14	**Beijing**	**14.6**	**-15.2**	**6.7**
15	Hubei	0.6	7.9	-8.0
16	**Hunan**	**5.9**	**-17.0**	**9.2**
17	Xinjiang	-4.4	7.8	-1.4
18	Shanxi	0.9	4.7	-3.6
19	Heilongjiang	0.8	12.2	-9.5
20	**Tianjin**	**8.7**	**-12.6**	**4.4**
21	**Inner Mongolia**	**5.7**	**-21.6**	**16.3**
22	Yunnan	0.0	1.9	-0.3
23	**Huizhou**	**3.8**	**-2.0**	**0.8**
24	**Chongqing**	**4.3**	**-17.4**	**11.4**
25	Tibet	-	-	-
26	Qinghai	-4.2	19.4	-11.7

27	Jilin	-1.7	11.5	-7.7
28	**Ningxia**	**2.4**	**-7.8**	**6.6**
29	**Jiangxi**	**10.0**	**-10.0**	**-2.3**
30	**Gansu**	**2.9**	**-7.2**	**4.5**
31	Hainan	-1.0	10.1	-7.0
	Total	**5.0**	**-9.0**	**4.6**

Notes: Percentage point change in the distribution of domestic value added exports by function between 2002 and 2012. RD refers to R&D activities; SAL to sales and marketing; FAB to fabrication activities. *Source*: Authors' calculations, see main text.

5.3 The activities of Chinese provinces in exports

Figure 3 identifies province-specific specialization patterns. In this figure, we plot provincial GDP per capita against the FS index for each individual province in 2012. A plot is given for each of the four functions. The horizontal lines in each plot separate province observations with FS indices below and above 1. The actual values for the FS indices for each province are given in Table 4, not only for 2012 but also for the beginning of the period under study (2002).

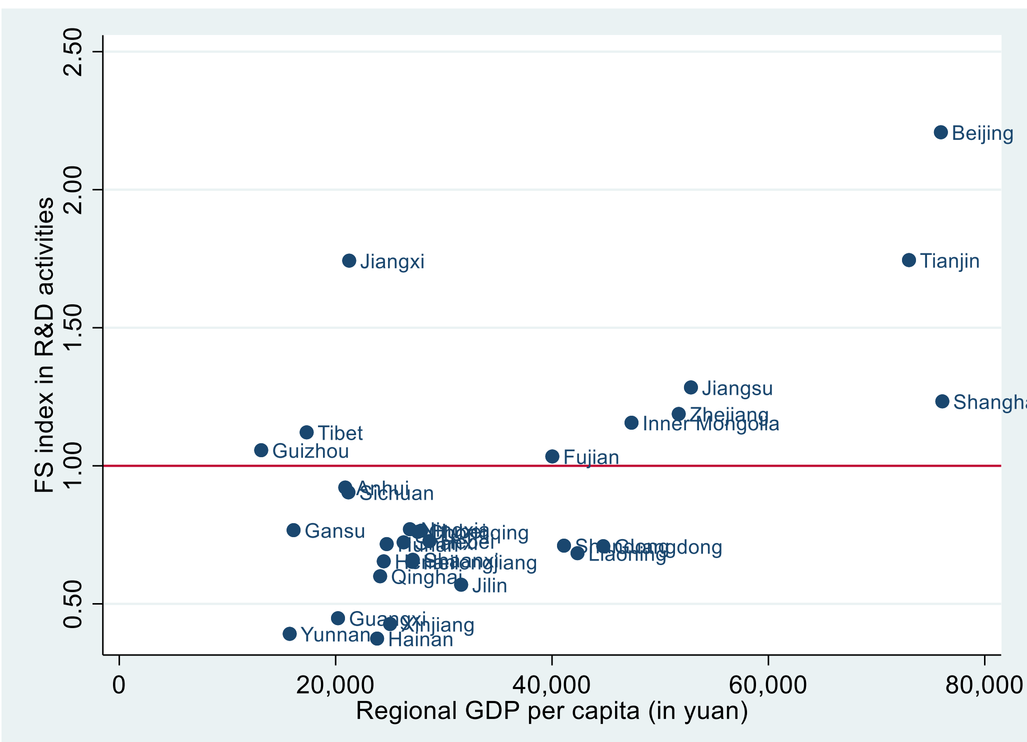
The first panel in Figure 3 shows that in 2012 richer provinces tend to have a higher FS index in R&D activities. Put otherwise, there is positive correlation between levels of economic development and functional specialization in R&D activities. Beijing, Shanghai and Tianjin have particularly high FS indices. Of these, only in Tianjin the FS index in R&D only marginally fell over the period from 2002 to 2012 (see Table 2). One can conclude that specialization in R&D is a common phenomenon for richer provinces in China. Note, however, that the is not a uniform pattern. For a given level of income, one province can be specialized in an activity whereas another province is not. For example, Jiangxi has an FS index in R&D activities well above 1, but Guangxi not, even though they are at similar levels of income per capita. Understanding what causes these differences in functional specialization in trade is an important and interesting avenue for future research. On the basis of the offshoring model by Feenstra and Hanson (1997) one might speculate it is driven by differential patterns in domestic value chain integration, e.g. due to spatial heterogeneity in transportation and communication links. But differences in specialization could also be driven by the size of the province, the attractiveness for multinational headquarter location, geographical characteristics and infrastructure, as well as historical built up of capabilities and networks.

The second and third panels in Figure 3 show FS indices in marketing and other support activities respectively. Some provinces, like Liaoning and Guangdong specialize in both activities in 2012. But other provinces seem to specialize in only one of them. Shanxi, and Tibet specialize in marketing activities, but not in other support activities. In contrast, Zhejiang, and Qinghai specialize in other support activities, but not in marketing. These varied patterns suggest that there are many idiosyncratic determinants of a province's specialization pattern.

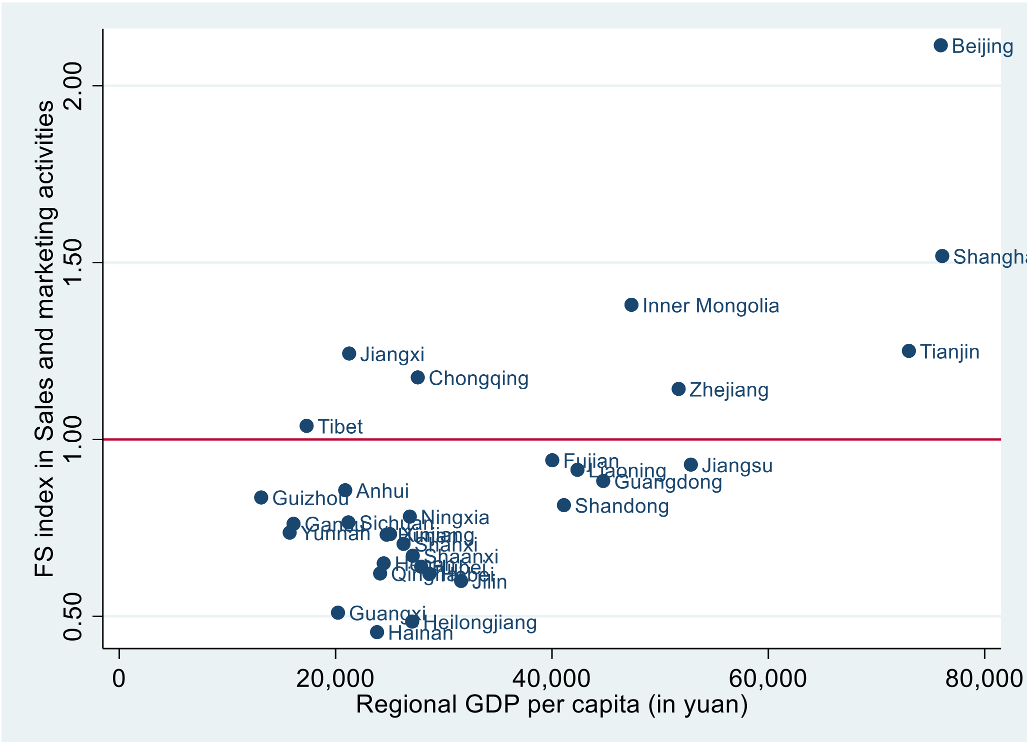
For lower-income provinces specialization patterns also vary widely. As expected, most of them are specialized in fabrication activities in 2012. They are mapped into the north-west quadrant in the last panel of Figure 3. Interestingly, many provinces in or close to the Pearl and Yangtze river delta in the (south-)east of China appear to specialize in fabrication activities.

Figure 3. Specialization by Chinese provinces in functions

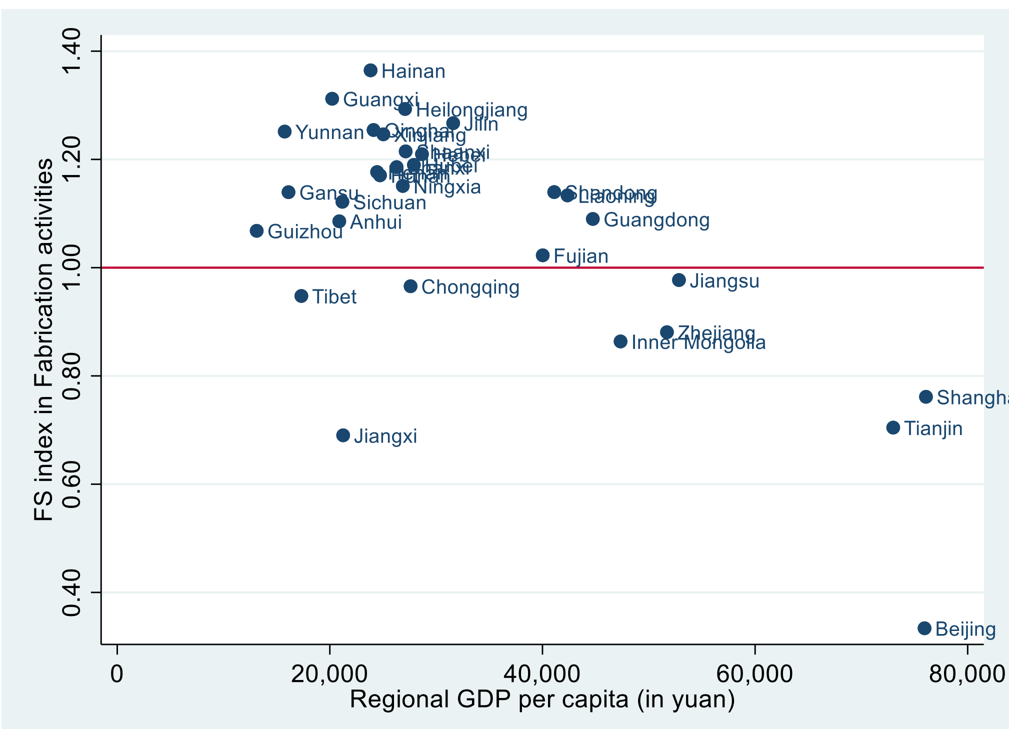
a. R&D activities



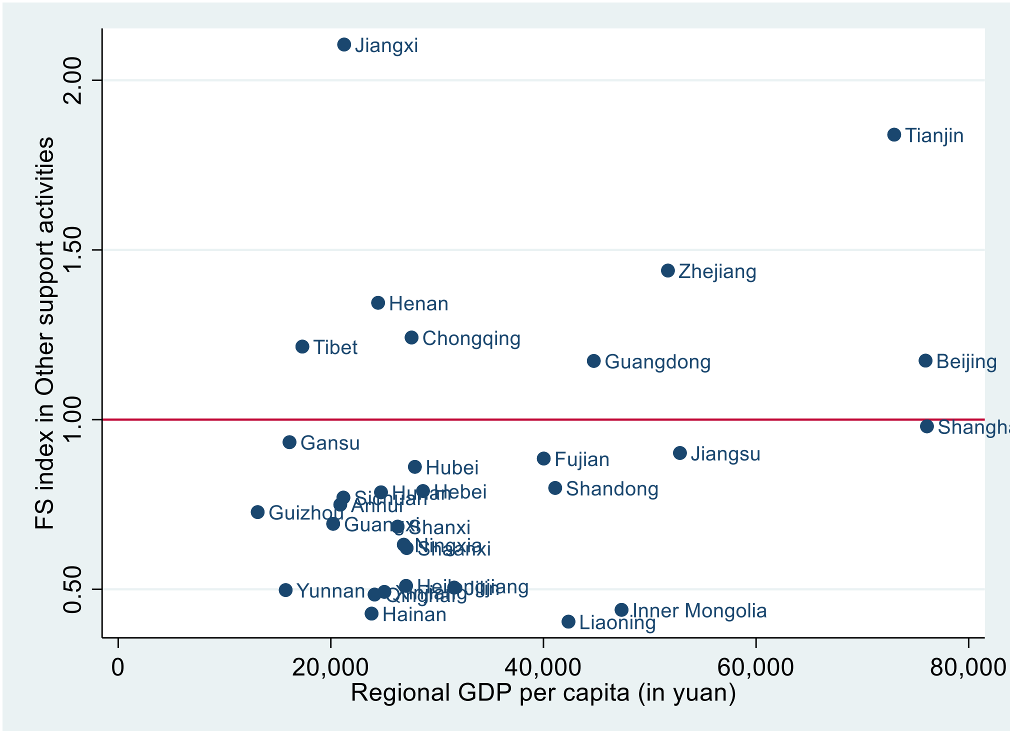
b. Sales and marketing activities



c. Fabrication activities



d. Other support activities



Notes: Provinces above the horizontal line indicate specialization in a function (FS≥1).
Sources: Authors’ calculations.

Table 4. Functional specialization by Chinese provinces.

#	Province	2002 RD	2002 FAB	2002 SAL	2002 OTH	2012 RD	2012 FAB	2012 SAL	2012 OTH
1	Guangdong	0.62	1.13	0.74	0.63	0.71	1.09	0.88	1.17
2	Jiangsu	0.98	0.96	1.10	1.21	1.28	0.98	0.93	0.90
3	Zhejiang	1.54	0.89	1.13	1.39	1.19	0.88	1.14	1.44
4	Shanghai	1.36	1.00	0.80	1.20	1.23	0.76	1.52	0.98
5	Fujian	1.40	0.95	0.97	1.21	1.03	1.02	0.94	0.89
6	Shandong	0.83	1.04	0.85	1.24	0.71	1.14	0.81	0.80
7	Hebei	1.00	1.04	0.81	1.18	0.73	1.21	0.62	0.79
8	Henan	1.41	0.84	1.44	1.06	0.65	1.18	0.65	1.34
9	Liaoning	1.37	0.91	1.22	0.88	0.68	1.13	0.91	0.40
10	Shaanxi	1.02	1.00	1.05	0.81	0.66	1.21	0.67	0.62
11	Guangxi	0.95	1.03	0.93	0.84	0.45	1.31	0.51	0.69
12	Sichuan	1.64	0.82	1.42	1.09	0.90	1.12	0.77	0.77
13	Anhui	1.07	1.05	0.81	0.81	0.92	1.09	0.86	0.75
14	Beijing	1.71	0.51	2.29	2.30	2.21	0.33	2.11	1.17
15	Hubei	1.24	0.92	1.24	0.84	0.76	1.19	0.64	0.86
16	Hunan	0.39	1.26	0.41	0.27	0.72	1.17	0.73	0.79
17	Xinjiang	1.36	0.97	0.99	0.86	0.43	1.25	0.73	0.49
18	Shanxi	1.12	0.97	1.08	1.01	0.72	1.19	0.70	0.68
19	Heilongjiang	1.01	0.95	1.13	1.20	0.65	1.29	0.49	0.51
20	Tianjin	1.76	0.79	1.33	1.69	1.75	0.70	1.25	1.84
21	Inner Mongolia	1.18	1.06	0.84	0.46	1.16	0.86	1.38	0.44
22	Yunnan	0.67	1.06	0.94	0.79	0.39	1.25	0.74	0.50
23	Huizhou	1.27	0.96	1.00	1.19	1.06	1.07	0.84	0.73
24	Chongqing	0.70	1.09	0.85	0.71	0.76	0.97	1.18	1.24
25	Tibet	-	-	-	-	1.12	0.95	1.04	1.22
26	Qinghai	1.63	0.82	1.42	1.18	0.60	1.25	0.62	0.48
27	Jilin	1.23	0.94	1.17	0.87	0.57	1.27	0.60	0.51
28	Ningxia	0.98	1.11	0.62	0.79	0.77	1.15	0.78	0.63
29	Jiangxi	1.58	0.74	1.69	1.30	1.74	0.69	1.24	2.11
30	Gansu	0.91	1.10	0.71	0.83	0.77	1.14	0.76	0.93
31	Hainan	0.79	1.04	0.96	0.82	0.37	1.36	0.46	0.43

Notes: RD refers to R&D; SAL to sales and marketing; FAB to fabrication activities; OTH to other support activities. Source: Authors' calculations, see main text.

6. Concluding remarks

In this paper we measured the contribution of provinces to China's gross exports. To implement our analysis, we collected rich data on the occupational structure of the labor force in combination with detailed information on the flow of intermediate inputs between province-industry pairs. We find that China's domestic value added in exports increased between 2002 and 2012. Our analysis suggests this is from an expansion of fabrication activities, mainly driven by provinces like Guangdong, Jiangsu, and Zhejiang.

However, there is clearly sub-national variation in domestic value added from activities in exports. To analyze this variation, we used an index of functional specialization in exports. This index reflects the new reality that most goods and an increasing number of services are "made in the world", and emphasizes competition in particular tasks within production networks, rather than on products. Our findings suggest that several provinces in China, most notably Beijing, Shanghai and Tianjin, have started to specialize in R&D and sales and marketing activities.

The results on functional specialization can inform, and complement, more qualitative research. It offers a useful macro-economic setting, charting patterns and trends that ground more detailed case and provincial level analyses. The results may also guide and motivate the choice of a particular sector or region for in-depth analysis which subsequently provides the needed full institutional and historical detail.

The data and approaches put forth in this paper provide a fertile ground to study the evolution of value chains in China building upon the pioneering work by Meng et al. (2013). This paper has documented trends and patterns in functional specialization. Understanding what is causing and providing a theory-based interpretation is an important next step.

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Appendix Tables

Appendix Table A1. Provinces in China

Beijing	Heilongjiang	Shandong	Chongqing	Qinghai
Tianjin	Shanghai	Henan	Sichuan	Ningxia
Hebei	Jiangsu	Hubei	Guizhou	Xinjiang
Shanxi	Zhejiang	Hunan	Yunnan	
Inner Mongolia	Anhui	Guangdong	Tibet	
Liaoning	Fujian	Guangxi	Shaanxi	
Jilin	Jiangxi	Hainan	Gansu	

Notes: These are the 31 provinces for which NBS provides survey-based provincial input-output tables. For 2002, a provincial input-output table for Tibet is not available.

Appendix TableA2. Industries distinguished

IO Code	Description	Business function share
1	Agriculture	agr
2	Coal mining, washing and processing	min
3	Crude petroleum and natural gas products	min
4	Metal ore mining	min
5	Non-ferrous mineral mining	min
6	Manufacture of food products and tobacco processing	low-tech man
7	Textile goods	low-tech man
8	Wearing apparel, leather, furs, down and related products	low-tech man
9	Sawmills and furniture	low-tech man
10	Paper and products, printing and record medium reproduction	low-tech man
11	Petroleum processing, coking and nuclear fuel processing	mid-tech man
12	Chemicals	mid-tech man
13	Nonmetal mineral products	mid-tech man
14	Metals smelting and pressing	mid-tech man
15	Metal products	mid-tech man
16	Common equipment	mid-tech man
17	Special equipment	high-tech man
18	Transport equipment	high-tech man
19	Electric equipment and machinery	high-tech man

20	Telecommunication equipment, computer and other electronic equipment	high-tech man
21	Instruments, meters, cultural and office machinery	high-tech man
22	Other manufacturing products	mid-tech man
23	Scrap and waste	mid-tech man
24	Metal products, machinery and equipment repair services	mid-tech man
25	Electricity and heating power production and supply	elec and const
26	Gas production and supply	elec and const
27	Water production and supply	elec and const
28	Construction	elec and const
29	Wholesale and retail trade	trade and distr
30	Transport, warehousing and post	trade and distr
31	Accommodation, eating and drinking places	trade and distr
32	Information communication, computer service and software	bus serv
33	Finance and insurance	bus serv
34	Real estate	bus serv
35	Renting and commercial service	bus serv
36	Scientific research and general technical services	bus serv
37	Water conservancy, environment, and public accommodation management	other serv
38	Household service and other social services	other serv
39	Education	other serv
40	Health service, social guarantee and social welfare	other serv
41	Culture, sports and amusements	other serv
42	Public management and social administration	other serv

Notes: 42 products distinguished in the provincial input-output tables. Product by product tables are transformed to industry by product tables, using the fixed product sales assumption.

Appendix Table A3. Mapping occupations to business functions

Code	Description	Business function
1	STATE ORGANS, PARTY AND MASS ORGANIZATIONS, ENTERPRISES AND INSTITUTIONS RESPONSIBLE PERSONS	

101	Communist Party of China Central Committee and local groups responsible organization	OTH
102	State organs and their agency heads	OTH
103	Democratic parties and social organizations and working bodies responsible persons	OTH
104	Institutional responsible persons	OTH
105	Enterprises responsible persons	OTH
2	PROFESSIONAL SKILL WORKERS	
201	Science researchers	RD
202	Engineering and technical personnel	RD
203	Agricultural technicians	RD
204	Aircraft and marine technology staff	RD
205	Health professionals	RD
206	Economic business staff	RD
207	Financial services personnel	RD
208	Legal professionals	RD
209	Teaching staff	RD
210	Literary arts staff	RD
211	Sports staff	RD
212	Journalism, publishing and cultural workers	RD
213	Religious professionals	RD
299	Other professional and technical personnel	RD
3	STAFF AND ASSOCIATED PERSONNEL	
301	Administrative office staff	SAL
302	Security and firefighters	SAL
303	Postal and telecommunications services personnel	SAL
399	Other staff and associated personnel	SAL
4	COMMERCIAL AND SERVICE PERSONNEL	
401	Purchasing officer	SAL
402	Warehouse staff	SAL
403	Catering staff	SAL
404	Hotel, tourism and recreation service personnel	SAL
405	Transportation service personnel	SAL
406	Health support services staff	SAL
407	Social services and living service personnel	SAL
499	Other commercial and service personnel	SAL
5	AGRICULTURE, FORESTRY, ANIMAL HUSBANDRY, FISHERIES AND WATER CONSERVANCY PERSONNEL	
501	Crop production staff	FAB
502	Forestry and wildlife protection officers	FAB
503	Livestock production staff	FAB

504	Fishery production staff	FAB
505	Water facilities management and maintenance staff	FAB
599	Other agriculture, forestry, animal husbandry, fishery and water conservancy production personnel	FAB
6	PRODUCTION, TRANSPORT EQUIPMENT OPERATORS AND RELATED WORKERS	
601	Survey and mineral exploration staff	FAB
602	Metal smelting, rolling staff	FAB
603	Chemical production staff	FAB
604	Machinery manufacturing and processing staff	FAB
605	Mechanical and electrical products assembler	FAB
606	Machinery and equipment repair staff	FAB
607	Electrical equipment installation, operation, maintenance and supply personnel	FAB
608	Electronic components and equipment manufacturing, assembly, commissioning and maintenance staff	FAB
609	Rubber and plastic products production staff	FAB
610	Weaving, knitting, dyeing and printing staff	FAB
611	Cutting, sewing and leather products processing production staff	FAB
612	Grain, food and beverage production, processing and feed production and processing staff	FAB
613	Tobacco and its products processing staff	FAB
614	Drug production staff	FAB
615	Wood processing and plywood production staff	FAB
616	Pulp, paper and paper products production and processing staff	FAB
617	Building materials production and processing staff	FAB
618	Glass, ceramics, enamel products production and processing staff	FAB
619	Radio and television producers, playback and conservation workers	FAB
620	Printing staff	FAB
621	Craft, crafts production staff	FAB
622	Culture, education, sports production staff	FAB
623	Construction workers	FAB
624	Transport equipment operators and related workers	FAB
625	Environmental monitoring and waste disposal staff	SAL
626	Test, measurement personnel	FAB
699	Other production, transport equipment operators and related personnel	FAB

7	SOLDIER	
700	Soldier	excluded
8	OTHER	
800	Other practitioners inconvenience classification	FAB

Notes: occupations distinguished in the China population census 2000 and 2010. Mapped into business functions. OTH refers to other support activities; RD to R&D; SAL to sales and marketing; FAB to fabrication activities.