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Regional inequality in China during its rise as a giant exporter: A value chain analysis

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Abstract

China's exports success has implications for regional income inequality, because most of its export products are manufactured in the coastal zone. We propose a value chain-based accounting framework to quantify the contributions of exports to regional income inequality. We employ newly developed interregional input–output tables for China, which distinguish between processing export activities and ordinary export activities. We analyze the period 2002–2012, the decade during which China became the "Factory of the World." We find that an RMB of processing exports contributed much more to regional inequality than an RMB of ordinary exports or domestic final demand. Still, changes in regional inequality (increasing in 2002–2007 and decreasing between 2007 and 2012) are much more due to rising ordinary exports in the first subperiod and the growth of domestic final demand coupled with changes in the configuration of value chains in the second.

KEYWORDS

capital income, input–output tables, processing exports, regional income inequality, value chains

1 | INTRODUCTION

In recent years, two of the most salient phenomena in the global economy have been a rapid increase in global interconnectedness and a significant rise in income inequality (Antràs et al., 2017; Storper, 2018). Decreases in trade and communication costs have allowed firms to split production processes into geographically distinct activities. Consequently, national and regional economies have specialized in those particular stages of production in which they have a comparative advantage. So-called global value chains (GVCs) emerged. By now, several studies have quantified the characteristics of GVCs and the roles countries play in these (e.g., Johnson & Noguera, 2012; Koopman et al., 2014; Los et al., 2015a; Timmer et al., 2014). These studies generally found substantial changes in the extent to which countries contributed to GVCs, and in the nature of these contributions (Timmer et al., 2019). Another strand of literature has studied the impact of intensified international trade on income distribution across regions within countries (see, e.g., Coşar & Fajgelbaum, 2016; Ezcurra & Rodríguez-Pose, 2013; Hirte et al., 2020; Marchand, 2012; Rodríguez-Pose, 2012; Wan et al., 2007). Many of these studies find that high levels of trade openness and high levels of regional inequality often co-occur.

This paper brings the above literatures together, and proposes a new accounting framework to investigate the effect of globalization on regional income inequality from a value chain perspective. We apply the framework to China, since it actively and successfully pursued prominence in the global trade network (in 2002–2012, the period considered in this study, China emerged as the "World's Factory" after its accession to the World Trade Organization in 2001), while it suffered from rapidly rising regional income inequality in the period in which it achieved this ambitious goal. This high regional inequality has become one of the major social and policy issues in China. After decades of increases, however, regional inequality in terms of gross domestic product (GDP) per capita has decreased in recent years (Li & Gibson, 2013; Xie & Zhou, 2014). This is illustrated by the decrease of the ratio of GDP per capita of the wealthiest province and the poorest province from 8.5 in 2000 to 4.5 in 2018.[1] China might thus have entered an era of convergence in regional development. This raises the question of whether exports have affected regional inequality differently in this era. Given these policy-relevant trends (and changes therein), the prominent role of the country in global production networks, and the availability of separate data for processing trade and ordinary trade, we consider China to be a natural case to study by means of our analytical framework.[2]

Our study fits into a much broader literature on China's uneven regional development. Björn and Li (2002), Kanbur and Zhang (2005), and Tsui (2007), for example, already argued that geographical factors played an important role in the fact that Chinese coastal regions developed much more rapidly than inland regions. Several studies have studied the relationships between globalization and regional inequality in China using regression analyses, and generally found a positive relation (see, e.g., Dai et al., 2020, 2021; Fujita & Hu, 2001; Jarreau & Poncet, 2012; Kanbur & Zhang, 2005; Lall & Lebrand, 2020; Li & Wei, 2010; Poncet & de Waldemar, 2013; Wan et al., 2007; X. Zhang & Zhang, 2003). However, reduced-form regression equations may not be appropriate in the presence of cross-regional general equilibrium effects (Adão et al., 2019), as they usually ignore the geographical linkages between economic activities. Chinese exports yield indirect income for inland regions through interregional input–output linkages, as the inland regions provide materials and components to the production of the exports in the coastal regions (Meng et al., 2017; Pei et al., 2017). Given this, this paper proposes an accounting framework to investigate the effect of exports to Chinese regional income inequality by taking the indirect interregional effects of exports fully into account.

The recent convergence in regional development also leads to the question whether changes in the relative importance of types of exports have contributed to changes in China's regional inequality. Until recently, "processing exports" and "ordinary exports," both accounted for about half of total exports.[3] These two types of export products use substantially different input mixes; processing exports require far more imported intermediate inputs than ordinary exports, and ordinary exports have stronger backward linkages in China (Pei et al., 2012).

[1]These provincial gross regional product (GRP) per capita levels were reported by the Chinese National Bureau of Statistics (NBS) and are expressed in current prices. In 2000, Beijing and Guizhou were the wealthiest province and the poorest province, respectively. Beijing and Gansu ranked as such in 2018.

[2]Processing trade refers to the business activities of importing all or some materials and components (under favorable conditions regarding tariffs, etc.), and then re-exporting the finished products after processing or assembly in China.

[3]After having accounted for about 50% of total exports since the 1990s, the share of processing exports has decreased steadily in recent years, to 33.5% in 2017.

Accordingly, a renminbi of processing exports tends to generate considerably less value added in China than a renminbi of ordinary exports (Chen et al., 2012; Koopman et al., 2012; Pei et al., 2012; Tang et al., 2020). If processing exports generate value added in China almost exclusively due to the exports processing itself, while ordinary exports have "longer" domestic parts of chains, it is probable that changes in the magnitudes of the two types of exports had impacts on regional income inequality.

Against this background, this paper aims to quantify the contributions of the two export types to China's regional inequality by taking "indirect income effects" into full consideration. We introduce a new framework to disentangle the major forces that shape China's regional inequality. We quantify the contributions of both processing exports and ordinary exports to regional inequality and examine changes over time, using a value chain perspective. Our accounting framework considers the Chinese parts of GVCs. The value of a particular final product (consumer products or capital goods) used in China or a particular exported product (either an intermediate input used by sectors abroad or a final product) equals the sum of the costs of imported products required in the Chinese stages of production and value added contributed by sectors in each of the Chinese regions. Consequently, the sum of these contributions by a region to all GVCs constitutes its GRP. We assume that labor income and production taxes add to the income of the region in which the production activities that generate these take place, while we estimate the interregional distribution of the associated capital income using data on interregional investment patterns. We use Shorrocks's (1982) decomposition method to quantify the contributions to regional inequality of value chain activities for domestically used final products and for exported products, respectively.

In summary, this paper contributes to the existing studies in at least three aspects. (1) We propose an accounting framework to investigate the effect of exports on Chinese regional income inequality by taking the geographical correlation and therefore the indirect exports into full account. By doing this, we go one step further based on the existing studies in GVC area by extending them from GVC accounting measures to the measures that reflect the effect of GVC on regional income inequality (Johnson & Noguera, 2012; Koopman et al., 2014; Los et al., 2015a; Timmer et al., 2014). (2) We distinguish between the heterogeneous effect of processing exports and ordinary exports on income inequality in China, by employing newly developed interregional input–output tables for China. (3) We measure regional income inequality using different income measures that include the interregional distribution of capital income.

The remainder of this paper is structured as follows: In Section 2, we summarize the nature of China's regional inequality to motivate the subsequent empirical exercise. In Section 3, we introduce the framework that decomposes overall regional inequality into the contributions of activities in the three types of value chains that we consider. In Section 4, we discuss the data. Section 5 presents our empirical results (including sensitivity analyses), and Section 6 concludes.

2 | REGIONAL INCOME INEQUALITY AND REGIONAL DISTRIBUTION OF EXPORTS IN CHINA

This section contains a brief descriptive overview of China's regional income distribution, and the distribution of its export activities. It thus provides some first insights into regional patterns of the economic phenomena of interest in the context of our analysis.

2.1 | Regional distribution of income and export activities

Table 1 documents descriptive statistics on exports and per capita income by region for 2002 and 2012. For each of these years, the first two columns depict regional income and GRP per capita (IPC and GPC), while the third and

TABLE 1 Regional product, income, and exports per capita (in 1000 RMB, current prices)

	2002				2012			
	IPC (1)	GPC (2)	PPC (4)	OPC (4)	IPC (5)	GPC (6)	PPC (7)	OPC (8)
NE	9.2	10.8	0.6	0.9	36.9	42.7	2.6	5.0
NM	47.5	26.6	3.8	6.3	133.9	85.0	7.6	19.8
NC	9.1	10.4	0.6	0.8	37.5	41.6	2.6	5.4
EC	15.2	18.0	2.5	4.4	58.5	64.5	12.1	18.1
SC	12.4	15.5	7.1	3.7	44.6	48.4	14.5	14.2
CR	6.0	6.4	0.0	0.2	28.0	30.0	0.6	1.3
NW	6.3	6.7	0.1	0.4	32.4	36.4	0.2	2.3
SW	5.2	5.3	0.1	0.2	23.9	25.8	0.4	1.6
National	9.0	9.6	1.2	1.3	37.7	39.8	4.0	6.2

Note: Authors' calculations are based on the IRIOP tables (Duan et al., 2022).

Abbreviations: CR, Central Region; EC, East Coast; GPC, GRP per capita; GRP, gross regional product; IPC, regional income per capital; IRIOP, Interregional input-output table caputuring processing trade; NC, North Coast; NE, North East; NM, North Municipality; NW, North West; OPC, Ordinary exports per capita; PPC, Processing exports per capita; SC, South Coast; SW, South West.

fourth columns list regional processing exports and ordinary exports per capita (PPC and OPC) for the eight regions.[4]

To measure the level of regional inequality, we would ideally use regional household income, which consists of wages and salaries, net business income, income from properties, and income from transfers. Throughout the analysis, we define regional income as the sum of labor income (wages, salaries, etc.) and capital income due to investments in China. These are the two components of income that we can link to production activities required for exporting. We cannot do this in a meaningful way for income related to remittances (by workers who redistribute part of their income to family living in other regions of the country), other types of transfers and capital income associated with outward foreign direct investment (FDI). Given that the eight regions that we consider are large, any biases introduced by the assumption that workers live in the region in which they work will probably be small.

To estimate capital income (flows of which are not bound by regional borders), we used an approach based on capital ownership information contained in the Chinese Business Registry Database (Registry Data hereafter) collected by the State Administration of Industry and Commerce (SAIC). Section 4 and Supporting Information Appendix 3 contain more information about how we estimated interregional capital income flows.

The GRP and exports data have been taken from the interregional input-output table caputuring processing trade (IRIOP) tables (Duan et al., 2022). The population data are from NBS (2003, 2013) and include only those persons actually living in each region, which implies that the dynamics of interregional labor migration are taken into consideration.

The figures for processing exports and ordinary exports per capita in Table 1 reveal sizable regional differences, especially for processing exports; exports were more concentrated in North Municipality, East Coast, and South Coast. In contrast, exports from the inland regions were extremely low; in 2012, for example, processing exports per capita in North West amounted to 200 RMB, which was only 5% of the national average. Focusing on the dynamics of exports, Table 1 reveals that processing exports have grown rather dramatically in East Coast, which almost caught up to the level of South Coast. Both East Coast and South Coast experienced rapid increases in terms of ordinary exports as well, with East Coast having a level only marginally lower than North Municipality, which includes the national capital Beijing,

[4]The eight regions analyzed here are those that are contained in the IRIOP tables. See Supporting Information Appendix 2 for the regional classifications. China in this manuscript indicates China mainland.

in 2012. Although the level of exports by inland regions was still considerably lower than those by coastal regions, growth rates were higher in these inland regions for the 2002–2012 period considered.

Table 1 also shows a large heterogeneity in income per capita across regions. The North Municipality is the wealthiest region, whereas the South West is the poorest. IPC and GPC are both much higher in the coastal regions (i.e., North Municipality, North Coast, East Coast, and South Coast) than in the inland regions (i.e., North East, Central Region, North West, and South West). However, IPC shows much less equal across regions than GPC. Large parts of capital invested in the eight regions are owned by investors in the North Municipality, and to a lesser extent, in other coastal regions. Hence, parts of GRP in other regions actually constitute capital income in coastal regions, which yields a more unequal distribution.[5]

From 2002 to 2012, IPC grew rapidly in all regions, with the national average increasing from 9.0 thousand RMB to 37.7 thousand RMB, at a nominal annual growth rate of 15.4%. The growth rates varied across China's regions, however, ranging from a high of 17.8% in North West to a low of 10.9% in North Municipality. In general, the inland regions show higher growth rates than the coastal regions, suggesting a decline in regional income inequality. Further, more rapid export growth in the inland regions suggests an important role of exports in this declining income inequality. We further describe the changes in China's regional income inequality over time in a more formal way in Section 2.2.

2.2 | Quantifying China's regional income inequality

The existing literature uses various measures to quantify inequality. Bourguignon (1979) and Shorrocks (1982) agreed on a set of simple principles that define a sound inequality index. The Theil (1967) index follows these principles and it is one of the most popular measures, because of its attractive decomposition property. This index measures the entropic distance between the actual distribution of income over regions and the benchmark state in which every region would have the same per capita income. A high value represents a large deviation from an equal distribution, which indicates a high degree of inequality. To measure regional inequality, we resort to a population-weighted version of the Theil index, expressed mathematically as

$$I = \sum_r p_r \frac{y_r}{\bar{y}} \ln\left(\frac{y_r}{\bar{y}}\right) = \sum_r \frac{v_r}{v} \ln\left(\frac{v_r}{p_r v}\right), \quad (1)$$

where p_r indicates the share of region r in the national population; y_r and v_r indicate the income per capita and total income in region r, respectively; and $\bar{y}$ is the national average of the income per capita, calculated as $\bar{y} = \sum_r p_r y_r$.[6] v is national income (NI).

We classify the regions into two larger geographic entities, which we call "macroregions": the coastal macroregion and the inland macroregion. We then decompose the overall regional inequality into the contributions of inequality between regions within the coastal macroregion (I_c), inequality between regions within the inland macroregion (I_i), and the inequality between the two macroregions (I_b) (see Supporting Information Appendix 2 for the classification of regions into macroregions):

$$\begin{aligned} I &= \sum_{r\in c} \frac{v_r}{v} \ln\left(\frac{v_r}{p_r v}\right) + \sum_{r\in i} \frac{v_r}{v} \ln\left(\frac{v_r}{p_r v}\right) \\ &= \frac{v_c}{v}\sum_{r\in c} \frac{v_r}{v_c} \ln\left(\frac{v_r}{p_{cr} v_c}\frac{v_c}{p_c v}\right) + \frac{v_i}{v}\sum_{r\in i} \frac{v_r}{v_i} \ln\left(\frac{v_r}{p_{ir} v_i}\frac{v_i}{p_i v}\right) \\ &= \frac{v_c}{v} I_c + \frac{v_i}{v} I_i + \frac{v_c}{v} \ln\left(\frac{v_c}{p_c v}\right) + \frac{v_i}{v} \ln\left(\frac{v_i}{p_i v}\right) = \frac{v_c}{v} I_c + \frac{v_i}{v} I_i + I_b, \end{aligned} \quad (2)$$

[5]At the national level, IPC is smaller than GPC. This is because some capital in China is owned by foreign investors. As stated before, the capital income of Chinese households due to outward FDI could not be taken into account in our analysis.

[6]We focus on regional income differences and do not consider income inequality between persons or households within regions.

in which c denotes the coastal macroregion and i the inland macroregion; v_c and v_i are total income in the two macroregions; p_{cr} and p_{ir} are the population share of a region r in the macroregion it is part of; finally, p_c and p_i are the population shares of the two macroregions in total population. Then, $v_c I_c/vI$, $v_i I_i/vI$, and I_b/I provide the contributions of I_c, I_i, and I_b to overall regional inequality, respectively.

Table 2 presents regional income inequality across the eight regions and its three components shown in Equation (2) for 2002, 2007, and 2012, the years for which the IRIOP tables are available. The regional income inequality measured with a Theil index amounted to 0.098 in 2002, slightly increased to 0.102 in 2007, and then rapidly decreased to 0.063 in 2012. In each year, inequality between the two macroregions was the major source, explaining more than half of China's total regional inequality. Furthermore, the inequality across regions within the coastal macroregion was much higher than that of across regions within the inland macroregion. An interesting finding is that the inequality within the inland macroregion decreased between 2002 and 2007 already, while reductions in inequality for the other components can be observed only after 2007.

To see whether these results based on the IRIOP tables that we will use for our accounting approach are in line with official data, we depict inequality in terms of GRP per capita for a more continuous and longer time series in Figure 1. The data is taken from the regional dataset compiled by the NBS. Regional income inequality shown in Table 2 is larger than that measured by GRP per capita in Figure 1, because of the uneven distribution of capital ownership discussed above. Even so, we find very similar trends.

TABLE 2 China's regional inequality considering interregional capital flows

	2002	2007	2012
Total regional inequality	0.098	0.102	0.063
Inequality within coastal macroregion	0.070	0.071	0.048
Inequality within inland macroregion	0.017	0.012	0.011
Inequality between coastal and inland macroregions	0.053	0.058	0.033

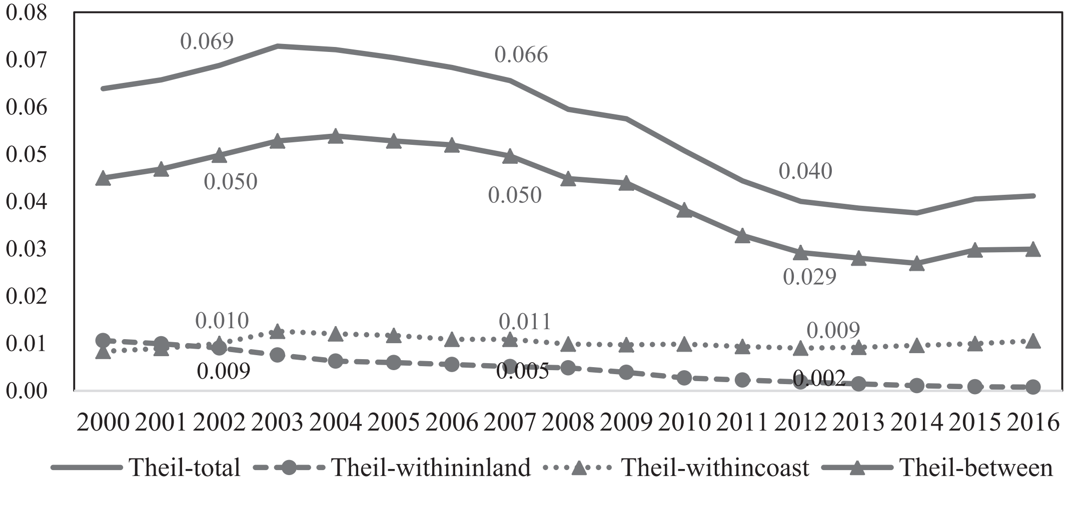

FIGURE 1 China's regional inequality in terms of GRP per capital from 2000 to 2016. Author's calculation based on the GRP and population data from NBS (various years). The income levels have been deflated to 2002 Beijing prices using the method of Brandt and Holz (2006). Section 4 explicitly describes the deflation procedure. GRP, gross regional product; NBS, National Bureau of Statistics.

Regional inequality increased rapidly from 2000 to 2003, remained stable until 2006, and then started to decrease. Inequality between the coastal and inland macroregions has been the major source of change, and regional inequality within the inland macroregion started to decrease a few years earlier than the other components of overall inequality. These results suggest that the data obtained from the IRIOP tables lead to results with similar features as results based on official data from NBS. This supports our claim that we can meaningfully address our main research question ("To what extent did changes in export levels and mixes contribute to changes in China's regional inequality?") by means of an accounting approach based on the IRIOP tables.

3 | METHODOLOGY

In this section, we propose a new framework to account for the contribution of exports to regional inequality. It contains two parts. First, we propose a method to split regional income in a region into parts attributable to specific final products, explicitly taking the structures of value chains into account. Second, using this method, we decompose overall regional income inequality into the contributions of each final product, building on Shorrocks's (1982) decomposition framework.

3.1 | Tracing value chains

We begin by estimating regional income generated in Chinese parts of value chains for final products. For some of these final products, the last stage of production takes place in China itself, whereas Chinese exports of intermediate products are directly or indirectly used for the production of final products abroad. In view of the fact that our interregional input–output tables are not nested in global input–output tables, we assume that these exports do not re-enter China in embodied form as inputs into more downstream stages of production and can therefore be considered as final products from the perspective of the Chinese economy.

We follow a decomposition technique originally introduced by Leontief (1936) and popularized in multicountry settings by Johnson and Noguera (2012), Timmer et al. (2014), Los et al. (2015a), and Reijnders and de Vries (2018), among others. We start by modeling the Chinese economy as an input–output structure, according to the idea that the production of final products requires primary inputs (labor and capital) and intermediate inputs, the production of which in turn also requires primary and intermediate inputs. By accounting for all intermediate inputs in each stage of production, Leontief (1936) provided a model in which the value of any particular final product can be decomposed into the values of all labor and capital employed in any stage of production. Accordingly, the input–output model can be used to measure how each final product contributes to the factor income of any given region. We apply Timmer et al. (2014) approach to a case in which the input–output table does not contain data for the global economy split into countries, but for the Chinese economy split into regions.

1. *Illustrative example: regional income for textiles production in East Coast*

To demonstrate our methodology, we start by discussing the value chain activities in China to produce the ordinary exports of the textiles sector in the East Coast region. We aim to calculate not only income in the final production stage on East Coast (taking into account that capital income generated on East Coast partly accrues to investors in other regions), but also income in more upstream activities in all regions, including East Coast (again taking into consideration that capital income often flows across regional borders). The data used are those contained in the IRIOP tables, which will be described in Section 3.2, alongside a formal discussion of the methodology. In 2002, every RMB of ordinary textiles exports from East Coast generated 0.727 RMB of Chinese income (see Table 3). Income on East Coast itself accounted for as much as 83.2% of this 0.727 RMB. This East

TABLE 3 Income shares in the domestic stages of the production of ordinary exports of East Coast textiles (% of exports)

	NI	NE	NM	NC	EC	SC	CR	NW	SW
2002	72.7	0.4	2.7	2.2	60.5	1.6	4.3	1.0	0.8
2012	77.3	1.2	3.1	2.5	56.8	1.8	7.7	3.1	1.1

Note: Authors' calculations with the IRIOP tables for 2002 and 2012 (Duan et al., 2022). The remaining share of value added (e.g., 27.3% in 2002) consists of foreign capital income derived from production in China and the costs of imports. Since the IRIOP tables do not provide information on the global production structure, we assume that imports into China do not embody Chinese income.

Abbreviations: CR, Central Region; EC, East Coast; NC, North Coast; NE, North East; NI, National income; NM, North Municipality; NW, North West; SC, South Coast; SW, South West.

Coast income included income earned in the textiles sector, but also in East Coast sectors that indirectly contribute to local textiles production and in such upstream sectors in other regions, through capital income paid as a return on investment by East Coast investors.

The Chinese income share in an RMB of ordinary textiles exports grew from 0.727 RMB in 2002 to 0.773 RMB in 2012. The income share contributed by inland regions grew faster than the share of East Coast and other coastal regions. For example, the income in the Central Region amounted to 4.3% of the exports considered in 2002, increasing to 7.7% in 2012.

This specific value chain may be not representative of the income generation due to exports at the macroeconomic level. In Section 3.2, we use our accounting framework to analyze income patterns for all product groups from all regions taken together.

2. *Attributing regional income to final products in a value chain framework*

In this subsection, we will explicitly describe the methodology to quantify the role of exports in the generation of regional income. An IRIOP table is a special interregional input–output table that divides a national economy into several regional sectors and each regional sector into two production types: production of processing exports and other production (including the production of ordinary exports). Supporting Information Appendix 1 outlines the schematic framework of the IRIOP table for a two-region case.

In this system, output in each sector in each region is produced using local production factors and intermediate inputs, which can be sourced from local markets, other domestic regions, or foreign countries. Output can satisfy final demands, be used as intermediate inputs in various regions, or be sold to other countries. In an economy with m regions and n sectors, the product market-clearing condition can be written as

$$x_{ir} = \sum_{s=1}^{m} \sum_{j=1}^{n} z_{(ir)(js)} + \sum_{s=1}^{m} d_{(ir)(s)} + e_{ir}, \tag{3}$$

in which x_{ir} is the output in sector i of region r, and $z_{(ir)(js)}$ is the value of product i in region r used as intermediate input by sector j in region s. Furthermore, $d_{(ir)(s)}$ indicates the value of products i provided by region r and used for the final use of region s, and e_{ir} is the value of product i provided by region r and sold to foreign countries. When we refer to a final product provided by region r, we refer to the product for which the final production stage is located in region r (the “region-of-completion,” in the terminology of Los et al., 2015a).

This market-clearing condition can also be expressed using matrix algebra. We use the two-region case as an example (i.e., $m = 2$) in which the national economy is divided into regions r and s. We use superscript P to denote the processing export variables and the superscript O to denote ordinary production variables. The n-elements vectors $\mathbf{x}_r^P$ and $\mathbf{x}_r^O$ indicate the sectoral output levels for production of processing exports subsectors and ordinary production subsectors, respectively, in region r; $\mathbf{e}_r^P$ and $\mathbf{e}_r^O$ indicate the sectoral values of processing exports and ordinary exports provided by region r; $\mathbf{d}_r^P$ and $\mathbf{d}_r^O$ indicate the amounts of domestically sold final products provided by region r. $\mathbf{d}_r^P$ is a vector consisting of zeros, because processing exports can by definition not be sold to domestic users. The $n \times n$ dimension matrix $\mathbf{Z}_{rs}^{OP}$ describes the intermediate deliveries of ordinary production subsectors from region r used as intermediate input by processing exports subsectors in region s, and $\mathbf{Z}_{rs}^{OO}$ indicates the intermediate deliveries of ordinary production subsectors from region r used as an intermediate input for ordinary production subsectors in region s. The product market-clearing conditions in Equation (3) can then be written as

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{d} + \mathbf{e}^P + \mathbf{e}^O \tag{4}$$

with $\mathbf{x} = \begin{pmatrix} \mathbf{x}_r^P \\ \mathbf{x}_r^O \\ \mathbf{x}_s^P \\ \mathbf{x}_s^O \end{pmatrix}$, $\mathbf{Z} = \begin{pmatrix} \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{Z}_{rr}^{OP} & \mathbf{Z}_{rr}^{OO} & \mathbf{Z}_{rs}^{OP} & \mathbf{Z}_{rs}^{OO} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{Z}_{sr}^{OP} & \mathbf{Z}_{sr}^{OO} & \mathbf{Z}_{ss}^{OP} & \mathbf{Z}_{ss}^{OO} \end{pmatrix}$, $\mathbf{d} = \begin{pmatrix} 0 \\ \mathbf{d}_r^O \\ 0 \\ \mathbf{d}_s^O \end{pmatrix}$.

The two types of exports are denoted by $\mathbf{e}^P = \begin{pmatrix} \mathbf{e}_r^P \\ 0 \\ \mathbf{e}_s^P \\ 0 \end{pmatrix}$ and $\mathbf{e}^O = \begin{pmatrix} 0 \\ \mathbf{e}_r^O \\ 0 \\ \mathbf{e}_s^O \end{pmatrix}$, and $\mathbf{u}$ is the summation column vector with all elements equal to 1. $\mathbf{A} = \mathbf{Z}(\hat{\mathbf{x}})^{-1}$ is the matrix with domestic input coefficients with dimensions ($2mn \times 2mn$), in which a hat indicates a diagonal matrix with elements of a vector on the diagonal. $\mathbf{A}$ describes the direct input requirements of all intermediate goods across sectors and regions per RMB of region-sector-specific output. Solving this equation for $\mathbf{x}$, we arrive at the fundamental input–output identity:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}(\mathbf{d} + \mathbf{e}^P + \mathbf{e}^O), \tag{5}$$

in which $\mathbf{I}$ is a ($2mn \times 2mn$) identity matrix with ones on the diagonal and zeros elsewhere. $(\mathbf{I} - \mathbf{A})^{-1}$ is the well-known Leontief inverse, which represents the region-subsector-specific output levels required per RMB of region-subsector-specific final demand.

Equation (5) links gross output levels to final demand. To link regional income to final demand, income coefficients are required. To do so, we denote labor income and taxes in sector i and region r by b_{ir}. In a similar vein, c_{ir} denotes all capital income generated in sector i in region r. Using the methods described in Supporting Information Appendix 3, we estimate the share of each region s in c_{ir}. These shares mainly depend on the relative importance of investors from s in sector i in r. We indicate these shares by h_{ir}^s. $c_{ir}h_{ir}^s$ then provides the capital income earned by region s from production in sector i in region r. Income in s associated with production in sector i in region r can then be expressed as

$$l_{ir}^s = \begin{cases} c_{ir}h_{ir}^s + b_{ir} & \text{if } s = r, \\ c_{ir}h_{ir}^s & \text{if } s \neq r. \end{cases}$$

Next, $w_{ir}^s = l_{ir}^s / x_{ir}$ gives the income of region s directly required to produce an RMB of output in sector i in region r. We create two row vectors, $\mathbf{w}_r^{sP}$ and $\mathbf{w}_r^{sO}$, given that the IRIOP table distinguishes two types of production. We derive the incomes of each region directly and indirectly required for a final product vector $\mathbf{f}$ by postmultiplying the matrix $\mathbf{W}$ with the gross outputs needed for the production of this final demand:

$$\mathbf{I} = \mathbf{W}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}, \tag{6}$$

with $\mathbf{W} = \begin{pmatrix} \mathbf{w}_r^{rP} & \mathbf{w}_r^{rO} & \mathbf{w}_s^{rP} & \mathbf{w}_s^{rP} \\ \mathbf{w}_r^{sP} & \mathbf{w}_r^{sO} & \mathbf{w}_s^{sP} & \mathbf{w}_s^{sO} \end{pmatrix}$. $\mathbf{f} = \mathbf{d} + \mathbf{e}^P + \mathbf{e}^O$ represents all final products in the system. Then the m elements in $\mathbf{I}$ indicate the total incomes in each region.

We obtain regional income generated in activities in value chains for each region-subsector-specific final product by diagonalizing the final demand vector in Equation (6). That is,

$$\mathbf{L} = \mathbf{W}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{f}} = \mathbf{W}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{e}}^P + \mathbf{W}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{e}}^O + \mathbf{W}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{d}} \equiv \mathbf{L}^P + \mathbf{L}^O + \mathbf{L}^D. \tag{7}$$

The element l_{1r}^s in the $m \times 2mn$ matrix $\mathbf{L}$ indicates the income of region s generated by the final demand for the product of the first subsector 1 in region r. Similarly, $\mathbf{L}^O$, $\mathbf{L}^P$, and $\mathbf{L}^D$ indicate the regional incomes that can be attributed to processing exports demand, ordinary exports demand, and domestic final demand for the outputs of every region-sector, respectively. Equation (7) thus allows us to decompose the total income of each region into shares induced by processing exports, ordinary exports, and domestic final demand. In what follows, we refer to the sum of $\mathbf{L}^P$ and $\mathbf{L}^O$ as "income from exports."

3.2 | Decomposing regional inequality by source

In this subsection, we aim to decompose overall regional inequality into the contributions of each type of final product, using Shorrocks's (1982) decomposition.

One of the well-known methods of decomposing inequality by income source is the Shapley decomposition, which evaluates how overall inequality would change if income from one source were eliminated (or replaced by its mean, to evaluate the marginal effect of this source; Shapley, 1953; Shorrocks, 1999). However, as Sastre and Trannoy (2002) showed, the Shapley decomposition has an important problematic feature: The contribution it assigns to any income source depends on the level of disaggregation, such that it is sensitive to the ways in which other sources are clustered. Shorrocks (1982) offers a unified approach to quantify the proportional contribution of income sources to overall inequality, which has been widely used (see, e.g., Chi, 2012; Tsui, 1998). We will use this approach viewing final products as income sources, using the approach outlined in the previous subsection (Equation 7). Shorrocks proved that this decomposition solution is unique in meeting a number of desirable decomposition principles, including symmetry, independence, and consistency.[7] Following Shorrocks (1982), the Theil index in Equation (1) can be modified to calculate the absolute contribution of each income source k to the overall inequality as

$$contrib^k = \sum_r p_r \frac{y_r^k}{\bar{y}} \ln\left(\frac{y_r}{\bar{y}}\right) = \left(\frac{\bar{y}^k}{\bar{y}}\right)\left[\sum_r p_r \frac{y_r^k}{\bar{y}^k} \ln\left(\frac{y_r}{\bar{y}}\right)\right] = \varnothing^k I(y^k, y), \tag{8}$$

in which y_r^k is the income per capita in region r received from income source k, p_r stands for the share of r in the national population, and $\bar{y}^k$ indicates the mean of the kth type of income per capita. Equation (8) indicates that two elements determine the absolute contribution of income source k to overall inequality: the share of income from source k in total income ($\varnothing^k = \bar{y}^k/\bar{y}$) and the inequality implied by the distribution of income from source k itself ($I[y^k, y]$). $I(y^k, y) = \sum_r p_r(y_r^k/\bar{y}^k)\ln(y_r/\bar{y})$ represents a "pseudo-Theil" index that captures the inequality regarding the kth income source.[8]

[7]Symmetry and independence properties ensure that the contribution of any income component to overall inequality is not affected by the way the components are numbered or named, or how many types of components are distinguished. The consistency property ensures that the sum of effects of all income sources yields the overall inequality (Paul, 2004). Shorrocks's decomposition also meets two other conditions: (1) the contribution of an income source to aggregate inequality is 0 if every region would receive the same income per capita from that source and (2) if overall inequality is divided into two income sources for which the distribution of one source is a permutation of the distribution of the other, they contribute equally to total inequality.

[8]The difference between $I(y^k, y)$ and the regular Theil index for the kth income source is in the second factor between parentheses ($y_r/\bar{y}$). It represents the ratio of income per capita in region r to the national average in the pseudo-Theil index, but the ratio of the kth type of income per capita in region r to its national average ($y_r^k/\bar{y}^k$) in the Theil index.

We derive the contribution share of the kth income source to overall inequality by dividing its absolute contribution by the overall inequality:

$$contrib\_sh^k = contrib^k / I, \tag{9}$$

with I the overall inequality, as shown in Equation (1). Observe that the shares add up to one (i.e., $\sum_k contrib^k = I$), because $\sum_k y_r^k = y_r$.

By using the decomposition method illustrated above, we calculate the contribution of each final product to overall inequality by adopting an accounting perspective. If we compute the inequality attributed to exports, we implicitly assume that the workers involved in the associated activities would not be employed in other activities in the absence of these exports. We believe this assumption is reasonable for China, given its initially massive rural surplus labor force (Carter et al., 1996; Chu et al., 2000), which was at least partly absorbed when it became an important exporter of manufactured products (Los et al., 2015b). Another assumption is that wage rates paid to workers producing for domestic final demand have responded uniformly across regions to the increasing export-driven labor demand. Such general equilibrium effects might well have been different across regions, but cannot be considered in our analysis. We think that the export boom has actually had stronger positive effects on wage growth in the coastal regions than elsewhere in China (Fan, 2019; Han et al., 2012). If so, our results would provide a lower bound on the regional inequality effects of China's growing exports.

4 | DATA

4.1 | IRIOP tables

Most of our variables are from Chinese interregional input–output tables that make the distinction between processing trade activities and regular production activities, the so-called IRIOP tables as constructed by Duan et al. (2022).[9] Supporting Information Appendix 1 presents the structure of these tables. The tables include value added (which is split into labor income, capital income, and production taxes), domestic final demand, exports, and interregional and intraregional production linkages between sectors. IRIOP tables are available for 2002, 2007, and 2012. The tables contain data for 17 sectors and cover eight regions (North East, North Municipality, North Coast, East Coast, South Coast, Central Region, North West, and South West; see Supporting Information Appendix 2 for the regional and sectoral classifications).

The variables in the IRIOP tables are expressed in current local prices. Product prices may differ significantly across time and space, which implies spatial and temporal differences in costs of living. This affects economic outcomes in general and inequality in particular. For this reason, we convert the regional income into levels expressed in Beijing 2002 prices by using spatial price deflators from Brandt and Holz (2006). These authors combined a detailed analysis of household expenditures and prices at the province level for the year 1990 with annual provincial consumer price indices (CPIs) to provide reliable estimates of spatial price deflators at the provincial level from 1984 to 2004. We extend their 2004 price deflator to 2012 by chaining the annual provincial CPIs. We then deflate all provincial price levels in 2002, 2007, and 2012 by taking the 2002 Beijing price as the benchmark, such that the 2002 Beijing price equals 1. Finally, we aggregate the provincial deflators

[9]Value added in input–output tables includes four components: compensation of labor, fixed asset depreciation, net production tax, and operating surplus. The labor income in this paper indicates the compensation of labor. To estimate the compensation of labor by sector by region and by production types, Duan et al. (2022) use data from various sources. The totals of labor compensation across industries for each region come from the NBS, the sector-specific labor compensations for the processing exports, and for ordinary production at the national level from the national tripartite IO tables of Chen et al. (2012), and the labor compensation at the level of sector-regions (without the distinction between types of production) from the IRIO tables of Zhang and Qi (2012).

to the regional level by using provincial consumption as weights to obtain the price deflators for the eight regions.[10]

4.2 | Regional attribution of capital income

Substantial investment flows across regions lead to parts of the capital income of one region accruing as income to owners of firms in other regions or countries (Ma et al., 2015; Timmer et al., 2014, 2019).[11] Since the aim of this paper is to link regional income inequality to the production of exported products and the intermediate inputs required for these, we should attribute the capital income to the regions where the capital owners are located. To do this, we employ the cross-region capital flow data from Chinese Registry Data collected by the SAIC. We briefly describe the steps to obtain our desired interregional capital income flow data from the Registry data here, and present the details in Supporting Information Appendix 3.

The Registry Data records comprehensive ownership information for all firms ever established in China from 1949 onwards, including information on registered location and year, exit year, primary four-digit industry, ownership types (domestic-owned firm or foreign-invested firm), amount of registered capital, and the annual capital contributed by each of its investors. There are four types of investors in the database—enterprises registered in China (Chinese firms hereafter), foreign firms registered abroad (foreign firms hereafter), individuals, and the government. The database allows us to trace the capital flows across regions and industries by aggregating the firm-level data to the region and sector levels.

A key problem is the existence of indirect capital flows due to firms' reinvestment activities. For example, a firm from region 1 invests in another firm in region 2, which in turn invests in a third firm in region 3. Capital in region 1 flows to region 2 via direct investment, and also flows to region 3 through a second-tier investment. In this three-region example, we can directly obtain the first-tier-capital flows from region 1 to region 2, and from region 2 to region 3 from the Registry Data. However, we cannot directly observe the capital flows from the ultimate investor (region 1) to region 3. To identify the ownership of the capital income in each region's production, we trace the investment chains and finally identify the ultimate investors. Our approach broadly resembles the probabilistic method to estimate the ultimate ownership of FDI stocks as proposed by Casella (2019). The detailed matrix algorithm is shown in Supporting Information Appendix 3. Finally, we obtain a matrix **H**, of which the element h_{ir}^{s} indicates the share of capital stock used in region r industry i's production owned by investors in region s. We then assume that the capital used in a certain region-industry has the same capital return no matter where the capital comes from. Under this assumption, we could attribute the capital income generated in each region-industry's production to the regions where its ultimate investors are located using h_{ir}^{s} (see the discussion of Equation 6). Supporting Information Appendix 3 also provides an overview of the interregional capital flows at the aggregated level and at the sector level. It shows, among other things, that (1) North Municipality was the region with the largest net capital outflows, and that (2) East Coast and South Coast, where Chinese exports are mainly concentrated, were characterized by relatively high shares of capital from foreign investors.

5 | EMPIRICAL RESULTS

In this section, we apply our framework to determine how each type of final product, and exports, in particular, contributed to regional inequality. To provide a comprehensive picture, we begin quantifying regional income earned in the Chinese parts of value chains. Next, we analyze the effect of exports on regional income. Finally, we address the contributions of exports to regional inequality in detail.

[10]Both provincial CPI and consumption data have been taken from the official NBS website (http://www.stats.gov.cn/english/Statisticaldata/AnnualData/).

[11]Capital income is defined as the sum of operating surplus and depreciation of fixed capital.

5.1 | Regional income earned in value chains

Equation (7) allows us to investigate the regional income distributions along value chains and examine their dynamics from 2002 to 2012. We distinguish 408 final products (17 products × 8 regions of completion × 3 final product categories).[12] We follow Los et al. (2015a) by aggregating the elements of each column of **L** into three parts: local income (LI), inland income (II), and coastal income (CI).[13] For the processing exports of sector j in region r, for example, we define

1. LI as $l^{P}_{(r)(ir)}$, indicating the income earned in the region where the last Chinese production stage takes place, (the region-of-completion); $l^{P}_{(s)(jr)}$ is the element of $\mathbf{L}^{P}$ in Equation (7) that indicates the income in region s generated by processing exports of sector i in region r.
2. II as $\sum_{s\in inland;\, s\neq r} l^{P}_{(s)(ir)}$, showing the income earned in inland regions other than the region-of-completion (if this region belongs to the inland macroregion).
3. CI as $\sum_{s\in coast;\, s\neq r} l^{P}_{(s)(ir)}$, that is, income earned in coastal regions, but excluding the region-of-completion (if this region belongs to the coastal macroregion).

The sum of LI, II, and CI yields the total NI in each value chain. For each value chain, we divide the four income measures by the value of the product sold to Chinese final users and foreign users, which yields three shares: the local income share (LIS), the inland income share (IIS), and the coastal income share (CIS). The national income share (NIS) is the sum of LIS, IIS, and CIS. We define the local share as LIS/NIS. It indicates the share of income generated in the exporting region in the Chinese national income as a whole from each value chain. If interregional fragmentation of production would not exist and the interregional capital income flows would be zero, these shares would be 100%.

Table 4 presents the average results for the three final product categories. For each category, the results are the final demand-weighted averages of the shares of each value chain in this group (17 × 8 = 136 value chains for each group). The bottom row for each year shows the weighted averages of shares in all 408 value chains.

We report three important findings. First, while the Chinese economy was characterized by increasing geographical fragmentation of production processes, the largest part of NI embodied in final products was still earned in the region-of-completion. In 2012, the average local share for all value chains was 64.9%. The fact that a lot of capital income generated in upstream production activities in inland regions accrues to ultimate investors in the intensively exporting coastal regions (see Supporting Information Table A.5) contributes to this rather high local share.

Second, income distributions along the value chains of the three types of final products appear to have been rather different, as expected. An RMB of processing exports generated far lower NI than the same amount of ordinary exports or domestic demand. Most inputs for processing export production are imported from foreign countries (see Yang et al., 2015). This is also reflected in lower degrees of domestic fragmentation for processing exports than for ordinary exports, with LISs amounting to 75.5% and 69.9%, respectively, in 2012.

Third, the decreasing local shares (over 2002–2012) indicate increasing domestic fragmentation of production processes, for all three final product types. This has not been a steady process, however: after 2007, substantial parts of the decrease in local shares before 2007 were undone, again for all three types of final products. This is most probably because of China's increased capabilities to produce high-quality intermediate inputs domestically (Kee & Tang, 2016), which improved the NIS and the local share from 2007 to 2012. IIS and CIS increased over the

[12]The three final product categories are processing exports, ordinary exports, and domestic final demands. For some sectors (e.g., agriculture and mining), processing exports are zero and therefore we actually have 406 value chains.

[13]The results in this subsection are based on income shares obtained from Equation (8) and have not been corrected for differences in price levels across regions and over time (see Section 4), since this subsection does not deal with income inequality.

TABLE 4 Income shares of final products, by type (in %)

	LIS	IIS	CIS	NIS	Local share
2002					
Processing exports	11.0	1.0	1.6	13.6	81.1
Ordinary exports	28.6	3.3	6.1	38.0	75.4
Domestic demand	31.7	4.2	8.6	44.5	71.2
Average	29.1	3.8	7.5	40.5	72.0
2007					
Processing exports	9.6	1.5	1.5	12.6	76.3
Ordinary exports	20.3	4.6	5.7	30.7	66.3
Domestic demand	21.8	5.9	8.2	35.8	60.7
Average	19.8	5.1	6.8	31.7	62.5
2012					
Processing exports	13.9	2.2	2.4	18.4	75.5
Ordinary exports	26.3	5.1	6.3	37.7	69.9
Domestic demand	27.6	6.6	9.2	43.4	63.7
Average	26.3	6.0	8.2	40.4	64.9

Note: Authors' calculations are based on the IRIOP tables (Duan et al., 2022). Local Share = (LIS/NIS) * 100, NIS = LIS + IIS + CIS.
Abbreviations: CIS, coastal income share; IIS, inland income share; LIS, local income share; NIS, national income share.

entire period. IIS grew more rapidly than CIS, indicating that increased regional fragmentation of Chinese parts of GVCs benefited inland regions more than coastal regions, which might be relevant for the dynamics of regional inequality (in view of the results presented in Table 2).

5.2 | Importance of exports for regional income

How did the contributions of exports to regional income compare to the contributions of final demands by domestic users? We decompose regional income into three sources: income earned in value chains for processing exports, income earned from the production of ordinary exports, and income earned in the production of output sold to domestic final users, using Equation (7). The calculations are based on the IRIOP tables again, and the results are further deflated into the 2002 Beijing price using the regional price deflators discussed in Section 4.

The columns in Table 5 present the share of each income source in regional income. The first figure in column (1), for example, indicates that in 2002, 2.0% of North East's income was generated by its direct or indirect participation in the production of China's processing exports. The bottom row gives the results for the national economy, using regional income levels as weights. As shown in Equation (8), these shares ($\varnothing^k$) are important to compute the absolute contribution of each income source to the overall regional inequality.

A first, not very surprising, observation from Table 5 is that exports contribute much more to the incomes of coastal regions than of inland regions. In 2002, the share of income due to exports ranged from a high of 27.9% (11.1% + 16.8%) in South Coast to a low of 6.1% (1.2% + 4.9%) in South West. Within the coastal regions and the inland regions, the contribution of exports to regional income also varied considerably. It was 27.9% for South Coast, but only 11.6% for North Coast (also part of the coastal macroregion) in 2002. In particular, the contribution of processing exports to South Coast's income was up to 11.1%, but less than 5% for other coastal regions.

TABLE 5 Shares of regional income induced by three types of final demand (%)

	2002			2007			2012		
	IPE (1)	IOE (2)	IFD (3)	IPE (4)	IOE (5)	IFD (6)	IPE (7)	IOE (8)	IFD (9)
NE	2.0	7.8	90.2	3.0	12.7	84.3	2.7	10.0	87.3
NM	3.6	14.6	81.8	5.7	21.8	72.6	3.2	15.2	81.6
NC	2.3	9.3	88.4	3.6	16.0	80.4	3.1	13.1	83.8
EC	4.5	18.7	76.8	10.3	23.7	66.0	6.5	17.8	75.7
SC	11.1	16.8	72.1	12.7	19.1	68.2	8.1	20.8	71.1
CR	0.9	5.3	93.8	2.4	10.8	86.9	1.9	7.2	90.9
NW	0.9	6.0	93.1	2.2	15.6	82.2	1.6	9.4	88.9
SW	1.2	4.9	93.9	1.5	8.6	89.9	0.9	6.7	92.3
Average	3.8	12.5	83.7	5.9	18.4	75.7	3.8	13.7	82.5

Note: Authors' calculations are based on the IRIOP tables (Duan et al., 2022).

Abbreviations: CR, Central Region; EC, East Coast; IFD, income from domestic final demand; IOE, income from ordinary exports; IPE, income from processing exports; NC, North Coast; NE, North East; NM, North Municipality; NW, North West; SC, South Coast; SW, South West.

A second observation is that regional income was mainly generated by domestic demand rather than by exports. Even in 2007, when they were most important, exports generated less than 25% of NI. This might be less in line with the idea that China had become the "Factory of the World" by then, but is less unexpected if the size of the domestic economy is considered. Although the scale of processing exports was almost equal to that of ordinary exports (see Table 1), its contribution to income was less than one-third the contribution of ordinary exports.

Although the magnitudes of the contributions of exports to regional income varied strongly, a third observation from Table 5 is that all regions experienced similar changes over time. Exports made increasing contributions to regional income from 2002 to 2007. Before the financial crisis, both processing exports and ordinary exports played increasing roles in generating regional income, with sharply rising shares of IPE and IOE. After the global financial crisis, however, their share decreased. The East Coast was a prime example, with its income share due to exports dramatically increasing by 10.8 percentage points from 2002 to 2007 and then remarkably declining by 9.6 percentage points from 2007 to 2012.

Figure 2 displays the sectors in which the exports contributed the most to regional income in each of the regions considered. Together, they accounted for 84.1% of the NI in exports in 2012. Two groups of products—*Textiles* (sector 4) and *Mechanical and electrical products* (sectors 10–12)—accounted for 53.6% of total Chinese exports and 45.4% of the NI involved. These national shares hide some regional variations. The exports of the two sectors mentioned accounted for as much as 56.4% and as little as 33.3% of the income due to exports from the East Coast and the North Municipality, respectively. In North Municipality (the region that includes Beijing), as much as one-third of income due to exports was generated by services exports. This is mainly due to the higher service export share in North Municipality's exports, which was 13.7% for *Trade and Transport* (sector 16) and 24.8% for *Other Services* (sector 17).

5.3 | Contribution of exports to regional inequality

1. *Decomposition of inequality by type of final product*

In this section, we apply Equations (8) and (9) to decompose overall regional inequality into the contributions of each type of final product. Table 6 presents the results. Included are the Theil indexes (which indicate regional

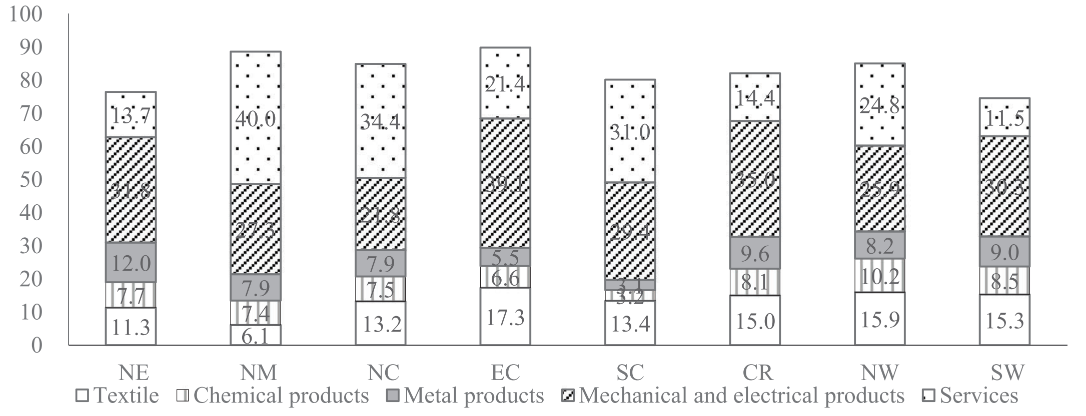

FIGURE 2 Regional income due to exports in 2012, by most important sectors (%, total regional income due to exports = 100). Authors' calculations are based on the IRIOP tables (Duan et al., 2022). *Mechanical and electrical products* are the aggregate of sectors 10–12. CR, Central Region; EC, East Coast; NC, North Coast; NE, North East; NM, North Municipality; NW, North West; SC, South Coast; SW, South West.

TABLE 6 Contribution of types of final products to regional income inequality

	IPE	IOE	IFD	TOT
2002				
Theil index	0.648	0.408	0.073	0.098
Contribution to total	0.009	0.029	0.059	
Share in total (%)	9.5	30.1	60.4	
2007				
Theil index	0.526	0.285	0.070	0.102
Contribution to total	0.015	0.037	0.050	
Share in total (%)	14.8	36.5	48.7	
2012				
Theil index	0.391	0.241	0.047	0.063
Contribution to total	0.007	0.020	0.036	
Share in total (%)	10.5	32.0	57.6	

Note: Authors' calculations are based on the IRIOP tables (Duan et al., 2018).

Abbreviations: IFD, income from domestic final demand, IOE, income from ordinary exports; IPE, income from processing exports; TOT, total regional income.

income inequality per type of final product and for all three types together), the contributions of the three types of the final product to total inequality, expressed in levels and in shares in 2002, 2007, and 2012.

The Theil index for income from the processing exports (IPE) is very high: 0.648 in 2002, more than 50% higher than that of IOE and eight times higher than that of IFD. Put differently, income along the value chains for processing exports was much more unequally distributed across regions than along the value chains of ordinary exports and domestic final demand. This is largely a result of the features of processing exports discussed before. The Theil index for IPE decreased over time, which indicates a convergence of income across regions, probably as a

TABLE 7 Contribution of sectoral exports to regional income inequality caused by all exports, 2012

Sectors	Theil index	Contribution share (%)	Sectors	Theil index	Contribution share (%)
Agriculture	0.195	0.0	Machinery	0.291	3.4
Mining	0.476	0.6	Transport equipment	0.285	2.0
Food	0.183	0.5	Electronic products	0.322	8.5
Textiles	0.262	4.7	Other manufacturing	0.475	0.7
Wood	0.173	0.7	Electricity, gas, and water	0.298	0.0
Paper and printing	0.366	0.7	Construction	0.416	0.1
Chemistry	0.201	2.6	Trade and transport	0.403	9.0
Nonmetallic minerals	0.102	0.4	Other services	0.871	6.3
Metal products	0.170	2.4	Sum	0.063	42.4

Note: Authors' calculations are based on the IRIOP tables (Duan et al., 2022).

consequence of the Chinese government's policy to increasingly locate processing exports activities in the inland macroregion. Increasing sourcing of inputs from other regions rather than from abroad may also have been an important contributor, enabling regions beyond the region-of-completion to benefit more from final product production.

Foreign demand proves to have been an important source of regional inequality. In 2012, processing exports together with ordinary exports explained 42.4% of overall regional inequality; ordinary exports alone explained 32.0%. Processing exports generated only a small share of total income, resulting in a limited contribution to regional inequality. These results resonate well with early studies that identify globalization as the main contributor to Chinese regional inequality (Kanbur & Zhang, 2005; X. Zhang & Zhang, 2003). We will provide a deeper analysis of the drivers of change in inequality in Section 5.4, but first pay some attention to the role of value chains for exports by specific sectors.

Table 7 lists the regional income inequality generated by exports by sectors and their contributions to overall inequality. The sum of their contribution shares equals the total contribution shares of processing exports and ordinary exports in 2012 listed in Table 6 (i.e., 42.4%). Income generated by exports of *Other services*, *Mining*, *Other manufacturing*, *Construction*, and *Trade and transport* were the most unequally distributed among regions, with Theil indexes higher than 0.4. However, as the second column reveals, the sectors that contributed most to China's overall inequality, are the five sector groups included in Figure 2, which generated the largest part of regional income induced by exports. Hence, these sectoral exports have large weights in the determination of total inequality: in 2012, their exports accounted for 38.8% of China's regional income inequality.[14]

2. *Quantifying the contributions of drivers of changes in regional inequality*

As discussed, China's regional inequality increased slightly from 2002 to 2007 and then sharply declined from 2007 to 2012. During this period, the contribution of exports to total inequality increased from 39.6% to 51.3%, and then decreased to 42.4% in 2012 (see the sums of IPE and IOE in Table 6). We have provided some potential explanations for these dynamics, most often based on previous literature. Our data, however, also allow for

[14]The number is obtained by summing up the contribution shares (Table 6) of the five sectoral groups in Figure 2.

TABLE 8 Accounting for changes in regional inequality in 2000–2007 and 2007–2012

		Processing exports			Ordinary exports			
		Scale	Composition	Chain configuration	Scale	Composition	Chain configuration	Domestic demand
	Actual	(1)	(2)	(3)	(4)	(5)	(6)	(7)
2007	0.102	0.096	0.102	0.100	0.086	0.103	0.126	0.117
2012	0.063	0.062	0.063	0.062	0.058	0.065	0.067	0.088

Notes: Authors' calculation is based on IRIOP tables (Duan et al., 2022). The row "2007" presents the results for 2007, while the row "2012" lists the results for 2012, assuming that only the actual changes indicated by the column headings would not have taken place.

investigations into the factors that drove the changes, along the lines of the accounting framework that we introduced.

We rewrite Equation (7), adding some variables. We denote $t^P = \mathbf{u'e}^P$ as the national scale of processing exports and $\mathbf{c}^P = \mathbf{e}^P/t^P$ as the composition of processing exports. $\mathbf{c}^P$ thus contains the shares of each sector in each region in the national value of processing exports. Similarly, we denote $t^O = \mathbf{u'e}^O$ and $\mathbf{c}^O = \mathbf{e}^O/t^O$, indicating the scale and composition of ordinary exports, respectively. This allows us to write

$$\mathbf{I} = \mathbf{W}(\mathbf{I} - \mathbf{A})^{-1}t^P\mathbf{c}^P + \mathbf{W}(\mathbf{I} - \mathbf{A})^{-1}t^O\mathbf{c}^O + \mathbf{W}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{d}. \tag{10}$$

The right-hand side of Equation (10) contains factors that determine regional income in a value chain context. These factors are the scale and composition of processing exports (t^P and $\mathbf{c}^P$), the configuration of the value chains for processing exports ($\mathbf{A}_{lk}^{OP}$ and $\mathbf{w}_k^P$), the scale and composition of ordinary exports (t^O and $\mathbf{c}^O$), the value chain configurations for ordinary production ($\mathbf{A}_{lk}^{OO}$ and $\mathbf{w}_k^O$), and domestic final demand (t^D and $\mathbf{c}^D$ combined).[15]

We identify the effect of changes in one particular factor at a time, by comparing observed inequality with inequality in the situation of no change in this factor at all (in the period considered) and assuming that all other factors changed as observed. If this "hypothetical" inequality was lower than the observed level, the actual change in this factor enhanced inequality, and vice visa. This is a partial equilibrium analysis within the framework of the demand-driven input–output model. It, for example, does not consider substitution effects due to changes in relative prices.

We analyzed seven hypothetical situations, for both 2007 and 2012. We recalculated Equation (10) by assuming that only one of the seven factors did not change (i.e., we assume that the values for 2002 still applied in 2007, and those for 2007 in 2012), while allowing the other six factors to change to their 2007 and 2012 values, respectively. Table 8 presents the results for regional income inequality across the eight regions. Taking the effect of the processing export scale as an example, Table 8 shows that if the scale of processing exports would have remained unchanged at its 2002 level while everything else had taken the 2007 values, regional inequality in 2007 would have been 0.096, a modest decrease compared with the actual level of 0.102. This implies that the increase in the scale of processing exports increased the regional inequality from 2002 to 2007, which is in line with our observation that processing exports are associated with more regional inequality than other types of the final output.

From 2002 to 2007, China's regional inequality slightly increased from 0.098 to 0.102 but then sharply decreased to 0.063 in 2012 (see also the last column in Table 6). From 2002 to 2007, changes in scales of

[15]Note that changes in the value chain configuration can relate to (1) the substitution of production in the sector itself by purchased inputs (or the reverse), (2) substitution of inputs from a region (or foreign countries) by inputs from a different region, and (3) substitution of inputs from one sector by inputs from a different sector.

processing exports and ordinary exports and the value chain configuration of processing exports increased inequality, whereas domestic final demands, the value chain configuration of ordinary production, and the composition of ordinary exports reduced inequality. However, from 2007 to 2012, processing exports had a negligible effect; the change in domestic final demand mainly drove the decrease. In contrast, the change in scales and value chain configurations of ordinary exports caused more inequality.

This analysis reveals three additional findings. Table 8 shows that the increasing scales of processing and ordinary exports were the main culprits of increasing inequality from 2002 to 2007. The IRIOP tables show that both processing and ordinary exports tripled, whereas domestic final demand merely doubled. Since the incomes earned from exports were very unequally distributed over regions, export growth significantly increased regional inequality from 2002 to 2007. In contrast, export growth led to only slightly more inequality from 2007 to 2012 since it grew by only 35% while domestic final demand increased by 112%.[16] This finding shows that China's recent "dual circulation" economic strategy that places a greater focus on the domestic market might be helpful in decreasing regional inequality.

Second, changes in the value chains for ordinary exports from 2002 to 2007 significantly reduced regional inequality. If the configurations of these value chains would have remained as in 2002, regional inequality in 2007 would have sharply increased to 0.126, instead of attaining its observed value of 0.102. This is mainly the result of inland regions getting more involved in value chains for ordinary exports by coastal regions. In 2002, for ordinary exports from the coastal macroregion, about 7.6% of intermediate inputs were provided by the inland regions; this share rapidly increased to 11.1% in 2007. This progress reduced the income gap between the coastal and inland regions, narrowing overall regional inequality. This suggests that China's regional policy of promoting the inland regions to more actively participate in GVCs has effectively decreased China's regional inequality.[17]

The third interesting finding is that the change in export compositions exerted a minor effect on regional inequality, even though export compositions underwent obvious changes in both commodity structure and geographic distribution. For example, Chinese exports shifted from labor-intensive products to products from high-tech sectors. According to the IRIOP tables, in 2002, about 17.8% of the exports were products from the *Textiles* sector, while the *Mechanical and electrical products* sectors accounted for 29.0% of these; in 2012, these shares had decreased to 11.8% and grown to 41.8%, respectively. With regard to the geographic distribution of exports (see Table 1), a considerable share of exports had shifted from South Coast to East Coast and North Coast. However, most of these shifts happened between coastal regions and made little difference to the overall inequality.

5.4 | Sensitivity analyses

In the analysis presented so far, we focused on regional income inequality considering a measure of income comprising labor income and capital income. Interregional income flows due to remittances were not taken into account, because we think that the data available to estimate such flows are not of sufficient quality. By making strong assumptions, we can get a good impression of how robust our baseline results are against the inclusion of remittances. We think that capital income associated with exports is an important source of regional inequality in China. Hence, we have included it in our baseline analysis, despite the assumptions that are needed to incorporate it. In the second part of this subsection, we analyze to what extent the results would change if we would exclusively focus on labor income, the source of household income that is most tightly linked to the location of production activities.

[16]The growth rates are in nominal terms and are calculated based on the IRIOP tables.

[17]The Chinese government launched different policies to encourage the processing sectors to move from advanced coastal regions to inland regions. For example, by extending the Economic and Technological Development Zones from the coastline to inland regions. It is important to note explicitly that our analysis cannot say anything about the role these policies have played, but the outcomes are in line with the objectives of these.

1. *Considering remittance income from interregional migrants*

In the baseline analysis, we attribute all labor income from the production to local residents. However, interregional migration is quite common in China. Many workers moved from rural areas to rich urban areas (Tombe & Zhu, 2019) and remitted substantial amounts of money to the region they originate from (Howell, 2017). According to De Brauw et al. (2002), migrants' remittances were the most important contributor to rural household income growth and may therefore alleviate spatial income disparity. In this subsection, we reinvestigate the contribution of globalization to the regional income inequality by taking migration and remittances into consideration. To do this, we consider an extreme case in which all interregional rural–urban migrants would transfer all their income home, that is to the region where their *hukou* is registered. Due to data limitations, we assume that workers who work in a given industry in a given region have the same wage, irrespective of their *hukou*. This exercise provides an upper estimate on the influence of interregional migration to our empirical results, since rural–urban migrants usually have a lower wage than a local residence, and only transfer part of their income home.

We obtained the interregional flows of migrants with rural *hukou* from Chinese census data for the years 2000 and 2010.[18] On the basis of this, we calculate the interregional migration shares g_r^s for any region, which indicates the share of migrants with rural *hukou* registered in region *s* in the total number of residents in region *r* (data limitations force us to assume that the workforces of all industries in *r* have the same share of workers with *hukou* in *s*). Then the regional income flow to region *r* due to production activities in region *s* as introduced in Section 3.1 becomes $l_{ir}^s = c_{ir}h_{ir}^s + b_{ir}g_r^s$. In the next step, we recalculate our empirical results following the procedures described in Section 3.1.

The upper panel of Table 9 shows the contribution of each type of final products to the regional income inequality in this exercise and Table 10 explores the contribution of each component to the changes in income inequality. As expected, slightly lower regional income inequalities are observed in Table 9 than in Table 6. This is because the migrants usually move from poor regions to rich regions, and therefore the remittance from rich regions to poor regions has shrunk the regional disparity. However, the other results are quite similar to our baseline results shown in Tables 6 and 8, including the income inequity along the value chain of exports, the contribution shares of exports to regional inequality, and the forces behind the region inequality changes over time. Given that we consider a rather extreme scenario regarding the size of remittances and the small differences with the baseline results this scenario yields, we feel that it is safe to state that the exclusion of transfers by interregional migrants in the baseline analysis did not cause substantial biases in the outcomes.

2. *Excluding interregional capital income flows*

In the baseline analysis, we estimate the interregional capital income flows based on the Registry Data. Due to the limited availability of data, this cannot be done without making several assumptions, some of which are strong (see Supporting Information Appendix 3 for details). Moreover, the data on capital investments that underlie our estimates might be affected by mismeasurement. To investigate how sensitive our empirical results are to these issues, we consider the case in which we do not consider the capital income at all, and focus solely on regional labor income inequality.

The bottom panel of Tables 9 and 10 shows the empirical results for this exercise. As expected, the regional inequality in terms of labor income is lower than in our baseline results. As mentioned already, this is mainly because the wealthiest regions in terms of labor income (North Municipality is the most important example) are also the regions with the largest investments in other regions as shown in Supporting Information Appendix 3, generating a lot of capital income elsewhere in the country. A comparison of Tables 6 and 9 also shows that these differences are mainly caused

[18]The data are taken from NBS (2002, 2012). These are the only available migration data that are close to the initial and final years of the period we study.

TABLE 9 Sensitivity of contributions of types of final products to regional income inequality to inclusion of household income components

Year		IPE	IOE	IFD	TOT
Baseline plus remittances by interregional migrants					
2002	Theil index	0.522	0.347	0.064	0.084
	Contribution to total	0.007	0.025	0.052	
	Share in total (%)	8.5	29.5	62.1	
2007	Theil index	0.463	0.254	0.064	0.091
	Contribution to total	0.013	0.033	0.045	
	Share in total (%)	14.2	36.1	49.7	
	Theil index	0.326	0.206	0.041	0.053
2012	Contribution to total	0.005	0.017	0.031	
	Share in total (%)	9.7	31.4	58.8	
Baseline minus interregional capital income flows					
2002	Theil index	0.694	0.327	0.026	0.046
	Contribution to total	0.008	0.019	0.020	
	Share in total (%)	16.9	41.0	42.1	
2007	Theil index	0.555	0.220	0.025	0.048
	Contribution to total	0.011	0.023	0.014	
	Share in total (%)	23.1	47.3	29.6	
2012	Theil index	0.456	0.214	0.016	0.029
	Contribution to total	0.006	0.014	0.009	
	Share in total (%)	19.9	46.7	33.4	

Note: Authors' calculations are based on the IRIOP tables (Duan et al., 2022).

Abbreviations: IFD, income from domestic final demand, IOE, income from ordinary exports; IPE, income from processing exports; TOT, total regional income.

by the regional income from domestic final demand, while the income inequalities caused by both types of exports are much more similar. This is very probably because of the different sector compositions of domestic final demand and exports. Services have a much larger share in domestic final demand than in exports (39.1% and 5.0%, respectively, in 2012). Since service sectors use higher shares of capital sourced from the coastal regions, not considering capital ownership would reduce the regional inequality of the income from domestic final demand.

The results in the bottom part of Table 10 based on labor income alone generally lead to the same conclusions as the baseline results presented in Table 8. From 2000 to 2007, the growth of exports of both types (the scale effects) led to more inequality, while changes in domestic final demand and the value chain configuration for ordinary exports had opposite effects. From 2007 to 2012, the major driver of the reductions in regional labor income inequality was changes in domestic final demand and the various factors related to changes in exports did not play a substantial role.

These sensitivity analyses show that the measured degrees of interregional income inequality depend on which components of household income are incorporated, but that the extent to which exports of both types have caused interregional income inequality (and changes therein) are rather insensitive to such choices.

TABLE 10 Sensitivity of accounting for changes in regional inequality to inclusion of household income components

		Processing exports			Ordinary exports			
		Scale	Composition	Chain configuration	Scale	Composition	Chain configuration	Domestic demand
	Actual	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Baseline plus remittances by interregional migrants								
2007	0.091	0.086	0.091	0.090	0.077	0.092	0.109	0.104
2012	0.053	0.053	0.053	0.053	0.050	0.056	0.059	0.074
Baseline minus interregional capital income flows								
2007	0.048	0.042	0.048	0.041	0.036	0.050	0.065	0.062
2012	0.029	0.028	0.029	0.028	0.026	0.031	0.026	0.052

Note: Authors' calculation is based on IRIOP tables (Duan et al., 2022). The row "2007" presents the results for 2007, while the row "2012" lists the results for 2012, assuming that only the actual changes indicated by the column headings would not have taken place.

6 | SUMMARY AND CONCLUSIONS

Using newly developed interregional input–output tables for China, we explored the contributions of both processing exports and ordinary exports to regional income inequality. These tables, which separate the production of processing exports from other production (which includes production of ordinary exports), allowed us to distinguish the Chinese part of the value chains of these two types of exports and identify their different effects on regional inequality.

This study contributes both methodologically and empirically. With regard to methodology, we proposed a new accounting framework to explore the contribution of exports to regional inequality from a value chain perspective. This framework fully accounts for a region's indirect exports, which arise through the provision of materials, components, and services to export production activities in other regions. This allows for a more comprehensive analysis of the contribution of exports to regional inequality.

Empirically, we use newly available capital flow data to incorporate interregional flows of capital income. We find that exports explained around half of China's regional income inequality in the period 2002–2012. Processing exports contributed little, although the value chain activities were very unequally distributed over regions. They generated only little income in China itself, due to its reliance on imported inputs, which implies that its consequences for income inequality remained limited. Rather, ordinary exports predominantly contributed to China's regional inequality. These accounted for 10%–16% of Chinese income and the regional income distribution within their value chains is much more regionally clustered than in value chains for domestically sold consumption and investment products.

The substantial decline of regional inequality in the period 2002–2012 has not been due to changes in exporting activity. Even though value chains for processing exports and for ordinary exports have become distributed more equitably among regions, in particular the growth in ordinary exports still had inequality-increasing effects. The increasing levels of domestic final demand and the changing value chain configurations of ordinary production—which have become more domestically fragmented, with inland regions increasingly involved—have been the main reasons for declining regional inequality. In this regard, the outcomes are in line with China's recent policy of stimulating domestic demand to decrease regional inequality.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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