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Offshore, re-shore, re-offshore: what happened to global manufacturing location between 2007 and 2014?

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The global manufacturing location is a dynamic result of competing relocation patterns (i.e., offshoring, re-shoring and re-offshoring). This paper proposes a systematic approach to simultaneously measuring the magnitude of those relocation patterns, overcoming the shortcomings of the existing measurements and establishing a data foundation for capturing the process-specific, industry-specific and country-specific features in different relocation patterns. The empirical evidence prior to 2014 confirms that: (i) re-shoring is more likely to be adopted in capital- or technology-intensive manufacturing; (ii) manufacturing production previously offshored to the high-income economies is much more locationally flexible and (iii) re-shoring, especially that in the labour-intensive industries, is more likely to happen with a higher degree of proximity between countries.

Keywords: production location re-configuration, offshoring, re-shoring, re-offshoring, industry relocation
JEL Classifications: C67, F23, L16, M11

Introduction

The COVID-19 pandemic and the associated disruption in the global value chain have highlighted the importance of supply-chain resilience, pushed the re-configuration of many global value chains and re-focused attention on the location (and re-location) of production (Brakman et al., 2020). In general, the dynamic configuration of the production location across the world is a result of three competing relocation patterns. As shown in Figure 1, they are (i) offshoring (production relocated from the home economy to the host economy), (ii) re-shoring (production relocated from the host economy and then back to the home economy) and (iii) re-offshoring (production relocated from the host economy to a third economy).

Offshoring denotes the relocation of production to foreign economies[1] (Wan et al., 2019). This phenomenon could be traced back to the 1960–1970s as a prominent pattern of manufacturing location that saw production activity move from the developed economies towards low-cost economies (with

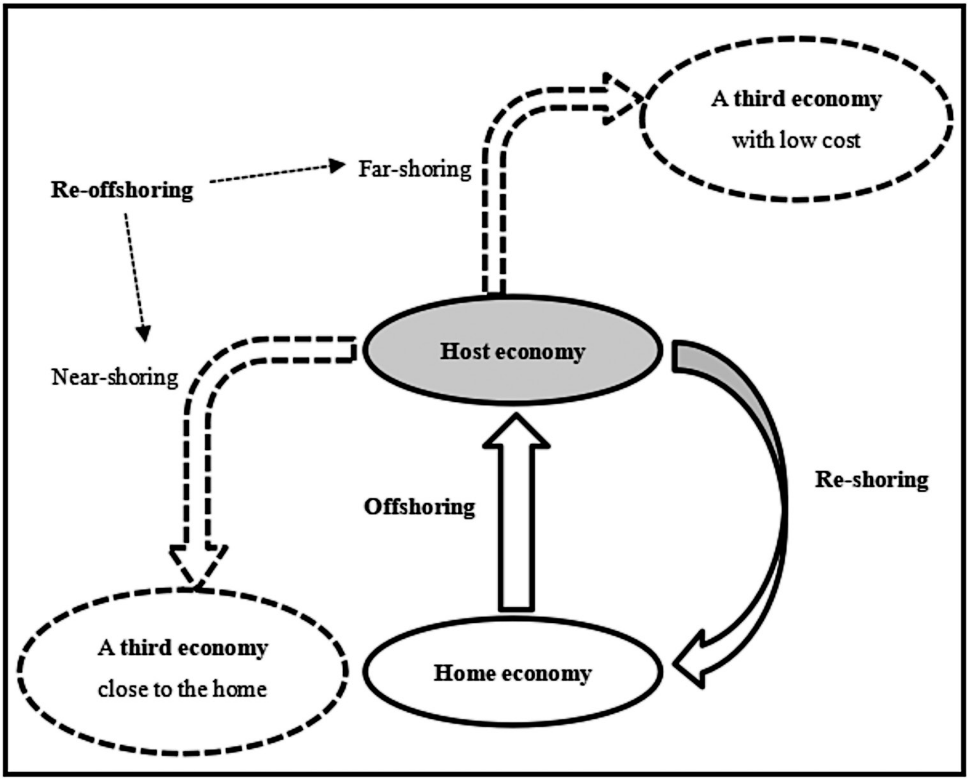

Figure 1. *The diagram of the location strategies in different directions.*

an earlier period in which production moved within countries, such as in the USA, with relocation from the Midwest and Northeast to the South). The process has accelerated since the beginning of the 21st century, driven by the rapid development of the Global Value Chain (GVC or Global Production Network, GPN; Coe et al., 2008). The opening of national markets in low-cost and high-growth economies provided the most prominent, attractive destinations for manufacturing offshoring. Some countries benefited significantly from this process; in particular, for example, the well-known depiction of India as 'the back-office of the world' (Dossani and Kenny, 2007; Jensen and Pedersen, 2011) and China as 'the factory of the world' (Lemoine and Ünal-Kesenci, 2004).

Although the advocates assert that offshoring would offer mutual benefits between home and host economy (Farrell and Angrawal, 2003; Farrell, 2005), there exist increasingly widespread concerns associated with offshoring, centring on job losses (Levy, 2005; Metters and Verma, 2008), quality risk (Gray et al., 2011) and logistical risk (Ritter and Sternfels, 2004). After experiencing sequential shocks generated by the global financial crisis in 2008, the 'Brexit' process, the US–China trade war and (in particular) the most recent COVID-19 pandemic, increasing uncertainties in the efficient functioning of GVCs have challenged some of the earlier expectations about global production location. Part of the previously offshored production has been relocated to the home economies since reliability was often valued more highly even if it costs more. This phenomenon is referred to as 're-shoring' (or 'on-shoring', 'back-shoring', Delis et al., 2019; Ellram, 2013;

Joubioux and Vanpoucke, 2016). The political economy dimension has seen re-shoring as an approach to enhance domestic economic recovery and restore industrial competitiveness, especially in Western Europe and the USA.

However, the previously offshored production can also choose to move towards third economies. On the one hand, faced with the diminishing cost advantage in the host economies (especially China), the offshored production might move to the third economy where the cost advantage can be maintained or enhanced, a process referred to as 'far-shoring' by Gadde and Jonsson (2019). On the other hand, considering the quality risk and supply chain inflexibility caused by greater distance, the offshored production might move to the third economy that is much closer to the home economy. This relocation pattern is referred to as 'near-shoring' (De Backer et al., 2016; Ellram et al., 2013). In this paper, both the 'far-shoring' and the 'near-shoring' are collectively referred to as 're-offshoring', namely changing the host economy of offshoring rather than moving back to the home economy. In recent years, the abundant labour resources, flexible investment environment and desire for rapid development have made the Global South a more attractive destination for offshoring or re-offshoring (Meng et al., 2018). At the same time, China, the primary host economy of manufacturing offshoring before the global financial crisis in 2008, has been confronted with the rapid increase in production factor prices, the tightening of environmental protection policies and the trade protection issues that are pushing production outside of China. Both tendencies have generated a trend in re-offshoring, although such a trend had already begun earlier in the past decade.

Taken overall, global production location is likely to change profoundly in the coming years (Brakman et al., 2020; Gereffi, 2020), but how it will change is becoming an increasingly important question. Addressing this question requires first and foremost the development of quantitative measures of the magnitude of the three relocation patterns (i.e., offshoring, re-shoring, re-offshoring) so that there is a basis on which to view current changes in the light of global production location re-configuration in the recent past. The paper proposes a systematic approach to simultaneously measuring the magnitude of offshoring, re-shoring and re-offshoring. As a prelude to the ongoing changes, the empirical analysis in this paper documents what happened to global production location prior to 2014, and the findings shed light on the *process-specific*, *industry-specific* and *country-specific* features in manufacturing re-shoring or re-offshoring.

The paper is organised as follows: the next section provides a review of the existing approaches measuring the magnitude of relocation patterns and their shortcomings. Thereafter, a set of hypotheses that will be tested later in the empirical section are put forward drawing on the economics literature. The Methodology section introduces the modelling process and economic explanation of the new proposed measurement of global industry relocation, and then provides an algorithm to classify the results of such measurement into three relocation patterns, i.e., offshoring, re-shoring and re-offshoring. The Empirical analysis section is based on the 2016 release of world input–output table (WIOT). In this section, the analyses in *process-specific*, *industry-specific* and *country-specific* dimensions are conducted and the re-configuration of global production location during the period 2007–2014 is revealed. In the final section. the paper concludes with a discussion of the results and their implications.

Literature review and hypotheses

Literature review

The research on offshoring, re-shoring and re-offshoring is increasingly prevalent in the supply-chain management (SCM), the international business (IB) and the GVC literature. However, the key topics focus on three major dimensions such as *why* offshore (or re-shore, re-offshore), *where* to move and *how* to implement the process, while the studies that focused on the magnitude of these relocation patterns are relatively limited (De Backer et al., 2016). In general, there exist three mainstream measurements of the magnitude of relocation patterns.

The first approach counts the offshoring or re-shoring cases based on surveys of enterprises, and then estimates the percentage that these cases comprise of all surveyed enterprises. This measurement is primarily adopted in the SCM or IB papers. Jensen and Pedersen (2011, 2012), using data from 1,504 firms located in the eastern regions of Denmark, found only 22% of them have made the offshoring decisions. Brennan et al. (2015), based on German data (1,594 companies) from the European Manufacturing Survey, found that the re-shoring has been undertaken by only 2% of German manufacturing companies from 2010 to mid-2012; in contrast, 8% of companies had undertaking offshoring. The Boston Consulting Group (2013) found 21% of surveyed US-based manufactures (a survey of 200 US-based manufacturing executives at companies with sales greater than $1 billion) have re-shoring plans. The survey-based measurements are straightforward and clearly indicate the magnitude of different relocation patterns for the survey sample. However, the data accessibility and sample representativeness of surveys varied in different regions or for different time periods, making comparability between different datasets very difficult (see De Backer et al., 2016). It might not be an important issue for SCM or IB papers since they are more focused on the *why* and *how* topics. However, if the intent is to provide a global view of the production location re-configuration, the prior measurements would not be suitable.[2]

The second issue is the measurement of the extent of dependence on imported intermediates using national input–output data and the associated models. Feenstra and Hanson (1999) estimated the extent of offshoring as the share of imported inputs in total costs. They found that this variable in the USA, averaged over all industries, increased from 5.3% in 1972 to 11.6% in 1990. Subsequently, Wright (2014) distinguished imported intermediate inputs from the imported final goods since there are often important differences in the nature of those products. Hummels et al. (2001) proposed a measure of Vertical Specialisation (VS) that highlighted the use of imported intermediates in producing exported goods. Using the Organization for Economic Co-operation and Development national input–output database, they estimated the magnitude of VS in 1995 to be about 30% of the world exports, representing a growth rate around 40% since 1970 and accounting for more than one-third of overall world export growth. They pointed out that the key insight of the high VS growth is the offshoring of the fragmented production process that was facilitated by trade barrier reduction and significant decreases in real transportation costs. Krenz and Strulik (2021) developed a metric of re-shoring by computing the change in the ratio between domestic inputs and foreign inputs. They found that the re-shoring intensity at the world level increased after the global financial crisis outbreak. These measurements are useful when focusing on a specific relocation pattern. However, when multiple relocation patterns are simultaneously taken into consideration, it is less likely to relate the change of such measurement to its underlying relocation patterns, because different relocation patterns may lead to the same change. For example, the decrease of VS would happen either in the home economy of re-shoring or in the original host economy of re-offshoring. Thus, the second type of measurement fails to accommodate all the relocation patterns in a systematic framework.

The third set of contributions are the GVC measurements and the Trade-in-Value-Added (TiVA) indicators. These measurements have been rapidly developed in the last decade, benefiting from the publication of the world input–output tables. Johnson and Noguera (2012) put forward a measurement of value-added exports (i.e., the value added produced in one economy and absorbed by another). Koopman et al. (2014) proposed the well-known KWW (Koopman, Wang and Wei) method that decomposes an economy's gross exports into the value-added exports, the value-added returned home, the foreign value-added and the double-counted terms. Los et al. (2016) proposed the 'hypothetical extraction' measurement framework as a more parsimonious alternative for the KWW method. Wang et al. (2017) decomposed the production into that for pure domestic demand, traditional international trade, simple GVC activities (i.e., exported intermediates that crossed the national border only once) and complex GVC activities (i.e., exported intermediates that crossed national borders more than twice).

The major advantage of the third type of measurement is it can recognise the sources of foreign value-added embodied in the production. Using this framework, Los et al. (2015) found that the increase of the value-added sourced outside the region (to which the country-of-completion belongs) is the main driver that raised the foreign value-added share since 1995, suggesting a transition from intra-region offshoring to the global offshoring. Guilhoto et al. (2019) explored the changes in international production systems based on the 2018 update to the OECD-TiVA database. They found that the shares of value-added originating from East and Southeast Asia increased both for North America, the European Union and the East and Southeast Asia from 2005 to 2015. These results were strongly influenced by the continuous growth of China and its share in the international trade. However, the value capturing capacity varied in different production processes (e.g., the 'Smile Curve', Meng et al., 2020). The advanced economies usually tend to engage in high-end processes (e.g., R&D and marketing) that capture most of the value-added, while offshoring the low-end processes (e.g., assembly) that add little value to the developing countries (a related phenomenon called 'Value-added erosion' in Heintz, 2006 and Caraballo and Jiang, 2016).[3] Thus, considering that the GVC measurements focus on changes of the value-added distribution but not the volume of production, these results may bias the magnitude of the relocation patterns.

Following the advantages of the third type of measurement, the present paper proposes a systematic approach to simultaneously measuring the magnitude of the relocation patterns using a world input-output framework, but from a production rather than a value-added perspective. This measurement establishes a data foundation for capturing the *process-specific*, *industry-specific* and *country-specific* features in different relocation patterns; some of them can be inferred from the existing literature (especially the SCM and IB papers).

Hypotheses

The resurgence in offshoring in the 21st century was driven by the rapid development of GVCs (Feenstra, 1998; Timmer et al., 2019), which distributed the sequential production process to different countries or regions to take advantage of differences in technologies, factor endowment, or factor prices across space (what Jones and Kierzkowski, 2001, refer to as the fragmentation of production). Thus, it is unlikely that the whole value chain will be re-shored as the total production cost will inevitably increase substantially. If this is the case, which phase of the production process (intermediate or final) is more like to be re-shored? Drawing on the literature that addresses the motivations behind re-shoring, the most cited reasons include the poor quality of offshore production (Gray et al., 2011), the 'made-in' reputation of the home country (Wan et al., 2019), intellectual property protection (Kazmer, 2014) and the concerns centred on supply chain inflexibility. Therefore, compared with the intermediate process, the re-shoring of the final process in the global value chain will contribute to (i) taking advantage of the 'made-in' reputation in the domestic market; (ii) encouraging the quality supervision of the products before they are delivered to final customers and (iii) enhancing the 'on-time-in-full' delivery performance. Thus, we hypothesise:

H1: The offshore production in the final processes of the GVC is more likely to be re-shored than the intermediate stages of production.

Although the diminishing cost advantage of low-wage countries provides another motivation for re-shoring, it seems that the re-shoring of labour-intensive manufacturing is not an ideal choice for the home countries. As Brennan et al. (2015) suggested, 'In many cases, it might be easier to build up capabilities for the next generation of products or technology, as re-learning of once outsourced competences can be a difficult process and provides only catching-up instead of leading positions'. A strand of literature has also provided evidence that the development of new generation techniques (e.g., automation, robotics and 3D printing) fuels reshoring in the developed countries (Faber, 2020; Krenz et al., 2021). On the one hand, those new generation techniques are usually more closely associated with capital- or technology-intensive manufacturing, whose production requires the participation of heavy/expensive machinery and equipment. On the other hand, the developed countries possess a clear advantage in knowledge resources and cross-border knowledge flows and thus are easier to rebuild competencies in capital- or technology-intensive manufacturing. On this basis, we propose the second hypothesis:

H2: The offshore production of the capital- or technology-intensive manufacturing is more likely to be re-shored than the offshore production of the labour-intensive manufacturing.

Jensen and Pedersen (2012) found that achieving international competitiveness through access to cross-border knowledge flows and foreign knowledge resources underlined the motives for advanced process offshoring, indicating that high-income countries are featured prominently as destinations for advanced process offshoring (due to their advantages in knowledge resources). Since the advanced processes are usually classified as capital- or technology-intensive manufacturing, if hypothesis 2 holds, the third hypothesis should also be true.

H3: The manufacturing production that was offshored to the high-income countries is more likely to be re-shored or re-offshored.

Distance and geography have been prominent considerations in the analysis related to changing locational advantages and are important underpinnings of the New Economic Geography (Fujita and Thisse, 2013) and the applications of gravity-based modelling (Anderson, 2011). As noted earlier, Delis et al. (2019) demonstrated that the effect of the driving forces of re-shoring declines when the distance between parent and subsidiaries becomes larger. One of the most likely explanations embodied in this result is that re-shoring from the location in the proximity of the home country provides easier access to (i) the supply chain of the original offshored subsidiaries and (ii) the market of the original offshoring location. As Baraldi et al. (2018) indicated, re-shoring means recreating (i) resource interfaces between the local inputs and the outputs of the re-shored activities and (ii) activity links between re-shored activities and the local network context. If the re-shored activities have limited options for resource support or require costly adaptions with several counterparts, the re-shoring company is likely to meet resistance by local contexts. In that case, the aforementioned access would contribute to mitigating these problems. Thus, we hypothesise:

> H4: re-shoring would be more likely to happen with the higher degree of proximity between countries.

In the next section, the article will propose a systematic approach to measuring the magnitude of offshoring, re-shoring and re-offshoring. Using this new approach, the hypotheses put forward in this section will be quantitatively tested in the empirical section.

Methodology

Measurement of global industry relocation

The starting point of the methodology is a newly proposed measure of global industry relocation using the inter-country input-output tables (Gao et al. 2018).[4] This measure subdivides the industry relocation into three components: (i) industry relocation driven by intermediate inputs, (ii) by final products and (iii) indirect intermediates relocation driven by final products. The simplified modelling processes drawn from Gao et al. (2018) based, for illustration, on a two-economy world are presented as follows.[5]

Assuming a two-economy (economy r and economy s) world, of which the input-output flows are recorded in Table 1 and each economy has N industries. Then, in Table 1, $\boldsymbol{Z}_{rs}$ is an $N \times N$ matrix of intermediates delivered from economy r to economy s; $\boldsymbol{f}_{rs}$ denotes an $N \times 1$ vector of the final products produced in economy r and consumed in economy s; v_r denotes an $N \times 1$ vector of the sectoral value added for economy r while $'$ denotes the transposition of a vector; $\boldsymbol{x}_r$ is an $N \times 1$ vector giving the gross output in economy r, which equals its total input.

The industry relocation driven by intermediate inputs

The industry relocation driven by intermediate inputs (denoted by $re^{1}_{ri,sj}$)[6] denotes the relocated intermediate production of industry i (in economy r) that is caused by the changes of spatial supply-shares in the intermediates used by industry j (in economy s).

Calculating the direct input coefficients from economy r to economy s as[7] $\boldsymbol{A}_{rs} = \boldsymbol{Z}_{rs}\hat{\boldsymbol{x}}_s^{-1}$, where $\boldsymbol{A}_{rs}$ denotes an $N \times N$ matrix of the inputs from economy r for per unit sectoral output of economy s. Define

$$\boldsymbol{A} = \begin{pmatrix} \boldsymbol{A}_{rr} & \boldsymbol{A}_{rs} \\ \boldsymbol{A}_{sr} & \boldsymbol{A}_{ss} \end{pmatrix}$$

as a $2N \times 2N$ matrix of global direct input coefficients and

Table 1. *World input-output table with two economies.*

		Intermediate use		Final demand		Gross output
		Economy r	Economy s	Economy r	Economy s	
Intermediate inputs	Economy r	$\boldsymbol{Z}_{rr}$	$\boldsymbol{Z}_{rs}$	$\boldsymbol{f}_{rr}$	$\boldsymbol{f}_{rs}$	$\boldsymbol{x}_r$
	Economy s	$\boldsymbol{Z}_{sr}$	$\boldsymbol{Z}_{ss}$	$\boldsymbol{f}_{sr}$	$\boldsymbol{f}_{ss}$	$\boldsymbol{x}_s$
Value added		$\boldsymbol{v}'_r$	$\boldsymbol{v}'_s$			
Total input		$\boldsymbol{x}'_r$	$\boldsymbol{x}'_s$			

Note: where $'$ denotes transpose of vector $\boldsymbol{x}$ and $\boldsymbol{v}$.

$$\boldsymbol{f} = \begin{pmatrix} \boldsymbol{f}_{rr} + \boldsymbol{f}_{rs} \\ \boldsymbol{f}_{sr} + \boldsymbol{f}_{ss} \end{pmatrix}$$

as a $2N \times 1$ vector of the final products produced in each economy. Denote 0 as the start year and 1 as the end year of the period. If the final products of the end year ($\boldsymbol{f}_1$) are produced in the start year, then according to classic Leontief input-output equation (Leontief, 1986), the hypothetical intermediate inputs can be calculated as:

$$\boldsymbol{C}_0 = \left[(\boldsymbol{I} - \boldsymbol{A}_0)^{-1} - \boldsymbol{I} \right] \hat{\boldsymbol{f}}_1 \tag{1}$$

where, $\boldsymbol{C}_0 = (c^0_{ri,sj})$ is a $2N \times 2N$ matrix that denotes the hypothetical intermediates supplied from industry i (in economy r) for producing the final products of industry j (in economy s) under the global direct input coefficients $\boldsymbol{A}_0$. Similarly, let

$$\boldsymbol{C}_1 = \left[(\boldsymbol{I} - \boldsymbol{A}_1)^{-1} - \boldsymbol{I} \right] \hat{\boldsymbol{f}}_1 \tag{2}$$

where $\boldsymbol{C}_1 = (c^1_{ri,sj})$ is a $2N \times 2N$ matrix that denotes the real intermediates supplied from industry i (in economy r) for producing the final products of industry j (in economy s) under the global direct input coefficients $\boldsymbol{A}_1$. Then, $\boldsymbol{C}_1 - \boldsymbol{C}_0$ denotes the changes of total intermediate inputs used for producing $\boldsymbol{f}_1$, a result driven by the evolution of global direct input coefficients from $\boldsymbol{A}_0$ to $\boldsymbol{A}_1$.

The evolution of direct input coefficients may originate from two causes. The first results from substitution between different inputs. For example, the automation equipment substitutes the labour input and the nuclear energy substitutes the fossil energy. The second is the spatial change of the supplier for a specific intermediate input, e.g., the coal supplier of the steel-making industry in economy r may change from economy r to s, leading to the industry relocation driven by intermediate inputs. Therefore, one needs to extract the impact of the second cause from $\boldsymbol{C}_1 - \boldsymbol{C}_0$.

In the two-economy world case, $\boldsymbol{C}_t$ ($t = 0$ or 1) can be represented as

$$\begin{pmatrix} \boldsymbol{C}_{tr} \\ \boldsymbol{C}_{ts} \end{pmatrix},$$

where the $N \times 2N$ sub-matrix $\boldsymbol{C}_{tr}$ denotes the intermediate inputs from economy r for producing the final products $\boldsymbol{f}_1$ under the global direct input coefficients $\boldsymbol{A}_t$. Hence, $\boldsymbol{C}^*_t = \boldsymbol{C}_{tr} + \boldsymbol{C}_{ts}$, where $\boldsymbol{C}^*_t$ is a $N \times 2N$ matrix, denoting the intermediate inputs from the whole world for producing the final products $\boldsymbol{f}_1$. Thereafter, we can show that[8]

$$\boldsymbol{R}_{tr} = \frac{\boldsymbol{C}_{tr} \cdot}{\boldsymbol{C}^*_t}, \qquad t = 0, 1 \tag{3}$$

where $\boldsymbol{R}_{tr}$ is a $N \times 2N$ matrix denotes the shares of intermediate inputs supplied by economy r under the global direct input coefficients $\boldsymbol{A}_t$. The $2N \times 2N$ matrix

$$\boldsymbol{R}_t = \begin{pmatrix} \boldsymbol{R}_{tr} \\ \boldsymbol{R}_{ts} \end{pmatrix}$$

denotes the shares of each economy of the world total. Hence, $\boldsymbol{C}_1 - \boldsymbol{C}_0$ can be decomposed as[9]

$$\boldsymbol{C}_1 - \boldsymbol{C}_0 = \begin{pmatrix} (\boldsymbol{C}^*_1 - \boldsymbol{C}^*_0) \circ \boldsymbol{R}_{0r} \\ (\boldsymbol{C}^*_1 - \boldsymbol{C}^*_0) \circ \boldsymbol{R}_{0s} \end{pmatrix} + \left[\boldsymbol{C}_1 - \begin{pmatrix} \boldsymbol{C}^*_1 \circ \boldsymbol{R}_{0r} \\ \boldsymbol{C}^*_1 \circ \boldsymbol{R}_{0s} \end{pmatrix} \right] \tag{4}$$

where the first term

$$\begin{pmatrix} (\boldsymbol{C}^*_1 - \boldsymbol{C}^*_0) \circ \boldsymbol{R}_{0r} \\ (\boldsymbol{C}^*_1 - \boldsymbol{C}^*_0) \circ \boldsymbol{R}_{0s} \end{pmatrix}$$

corresponds to the impact of substitutions between different inputs and the second term

$$\left[\boldsymbol{C}_1 - \begin{pmatrix} \boldsymbol{C}^*_1 \circ \boldsymbol{R}_{0r} \\ \boldsymbol{C}^*_1 \circ \boldsymbol{R}_{0s} \end{pmatrix} \right] = \begin{pmatrix} \boldsymbol{C}^*_1 \circ (\boldsymbol{R}_{1r} - \boldsymbol{R}_{0r}) \\ \boldsymbol{C}^*_1 \circ (\boldsymbol{R}_{1s} - \boldsymbol{R}_{0s}) \end{pmatrix}$$

corresponds to the impact caused by the change of the supplier, which is the measurement of the industry relocation driven by intermediate inputs. Thus:

$$\boldsymbol{RE}1 = \left(re^1_{ri,sj}\right)_{2N\times 2N} = \left[\boldsymbol{C}_1 - \begin{pmatrix} \boldsymbol{C}_1^* \circ \boldsymbol{R}_{0r} \\ \boldsymbol{C}_1^* \circ \boldsymbol{R}_{0s} \end{pmatrix}\right] \quad (5)$$

where $re^1_{ri,sj}$ denotes the relocated intermediate production of industry i (in economy r) that is caused by the changes of spatial supply-shares in the intermediates used by industry j (in economy s). If $re^1_{ri,sj} > 0\,(<0)$, it implies that changes in the intermediates used by industry j (in economy s) relocate the intermediate production of industry i into (out from) economy r.

The industry relocation driven by final products

The industry relocation driven by final products (denoted by $re^2_{ri,sj}$) denotes the relocated final-product production of industry i (in economy r) that is caused by the changes of spatial supply-shares in the final products consumed in economy s.

Define

$$\boldsymbol{ff} = \begin{pmatrix} \boldsymbol{ff}_r \\ \boldsymbol{ff}_s \end{pmatrix} = \begin{pmatrix} \boldsymbol{f}_{rr} + \boldsymbol{f}_{sr} \\ \boldsymbol{f}_{rs} + \boldsymbol{f}_{ss} \end{pmatrix}$$

as a $2N \times 1$ vector that denotes the final products *consumed* in each economy.[10] Define $\boldsymbol{FC}$ as a $2N \times 2N$ matrix giving the share of the final products supplied by each economy. In the two-economy world case:

$$\boldsymbol{FC} = \begin{pmatrix} \widehat{\boldsymbol{f}_{rr}\cdot/\boldsymbol{ff}_r} & \widehat{\boldsymbol{f}_{rs}\cdot/\boldsymbol{ff}_s} \\ \widehat{\boldsymbol{f}_{sr}\cdot/\boldsymbol{ff}_r} & \widehat{\boldsymbol{f}_{ss}\cdot/\boldsymbol{ff}_s} \end{pmatrix} \quad (6)$$

Then, the industry relocation driven by final products is measured as:

$$\boldsymbol{RE}2 = \left(re^2_{ri,sj}\right)_{2N\times 2N} = (\boldsymbol{FC}_1 - \boldsymbol{FC}_0) * \widehat{\boldsymbol{ff}_1} \quad (7)$$

where, $re^2_{ri,sj}$ denotes the relocated final-product production of industry i (in economy r) that is caused by the changes of spatial supply-shares in industry j's final products consumed in economy s. If $re^2_{ri,sj} > 0(<0)$, it means such changes in industry j's final products consumed in economy s relocate the final-products' production of industry i into (out from) economy r. Obviously, when industry i and industry j are not the same, $re^2_{ri,sj} = 0$.

The indirect intermediates relocation driven by final products

The final-products production in different locations relies on different domestic and international supply chains; the industry relocation driven by final products affects the location of their intermediate inputs. Based on the Leontief input-output model, the industry relocation of final products will lead to the change of intermediate inputs as:

$$\boldsymbol{RE}3 = \left(re^3_{ri,sj}\right)_{2N\times 2N} = \left((\boldsymbol{I} - \boldsymbol{A}_0)^{-1} - \boldsymbol{I}\right) * (\boldsymbol{RE}2) \quad (8)$$

where $re^3_{ri,sj}$ denotes the relocated intermediate production of industry i (in economy r) that is caused by the changes of spatial supply-shares in industry j's final products consumed in economy s. This is the indirect intermediates relocation driven by final products. If $re^3_{ri,sj} > 0$ (<0), it means such changes in industry j's final products consumed in economy s relocate the intermediates production of industry i into (out from) economy r. Supplementary Appendix A provides three numerical examples corresponding to the three types of industry relocation, to enhance the economic intuition for the measurement.

Measurement of global offshoring, re-shoring and re-offshoring

In this section, the paper will develop an algorithm to classify the results of global industry relocation into three relocation patterns, i.e., offshoring, re-shoring and re-offshoring. Considering that an offshoring activity must have occurred before the corresponding re-shoring or re-offshoring activities (Gray et al., 2013), this algorithm presumes a benchmark period when offshoring dominates the relocation patterns and then identifies different relocation patterns in the reporting period by comparing the results of global industry relocation between two periods.[11] The algorithm is presented in 5 steps as follows:

Step 1: measure the global industry relocation in the benchmark period

Denote $re^{k,0}_{ri,sj}$ for the result in the benchmark period, where $k = 1,2,3$ corresponding to the industry relocation driven by intermediate inputs, by final products and indirect intermediates relocation driven by final products, respectively; if $re^{k,0}_{ri,sj} > 0$, then economy r is the destination of industry i's offshoring driven by the changes from the industry j in economy s[12]. Otherwise, if $re^{k,0}_{ri,sj} < 0$, then economy r is the home economy of industry i's offshoring. Note that, for each offshoring activity, there will be a positive result for the host economy and, at the same time, a negative result for the home economy.[13]

Step 2: measure the global industry relocation in the reporting period

If $re^{k,1}_{ri,sj}$ is the result in the reporting period, by comparing $re^{k,1}_{ri,sj}$ and $re^{k,0}_{ri,sj}$, the economy r can be classified into four mutual exclusive sets:

(1) $\{++ \mid s,i,j\} = \left\{r \mid s,i,j, re^{k,0}_{ri,sj} > 0 \text{ and } re^{k,1}_{ri,sj} > 0\right\}$, in which industry i's production is relocated into economy r in both periods driven by the changes from the industry j in economy s;

(2) $\{+- \mid s,i,j\} = \left\{r \mid s,i,j, re^{k,0}_{ri,sj} > 0 \text{ and } re^{k,1}_{ri,sj} < 0\right\}$, in which industry i's production is relocated into economy r in the benchmark period, but out from there in the reporting period;

(3) $\{-+ \mid s,i,j\} = \left\{r \mid s,i,j, re^{k,0}_{ri,sj} < 0 \text{ and } re^{k,1}_{ri,sj} > 0\right\}$, in which industry i's production is relocated out from economy r in the benchmark period, but back to there in the reporting period;

(4) $\{-- \mid s,i,j\} = \left\{r \mid s,i,j, re^{k,0}_{ri,sj} < 0 \text{ and } re^{k,1}_{ri,sj} < 0\right\}$, in which industry i's production is relocated out from economy r in both periods.

Thus, the industry relocation in the reporting period can be classified into three relocation patterns, as shown in Figure 2.

Step 3: measure the magnitude of re-shoring in the reporting period

The re-shoring means moving the previously offshored production back to the home economies. Thus, for each specific s, i, j, re-shoring must correspond to the industry relocation from $\{+- \mid s,i,j\}$ to $\{-+ \mid s,i,j\}$. If

$$\sum\nolimits_{r\in\{-+ \mid s,i,j\}} \left|re^{k,1}_{ri,sj}\right| \le \sum\nolimits_{r\in\{+- \mid s,i,j\}} \left|re^{k,1}_{ri,sj}\right|,$$

it means the production relocated out from the host economy (where the offshoring relocates in during the benchmark period) exceeds the production relocated into the home economy. Thus, for $r \in \{-+ \mid s,i,j\}$ (the home economy), the magnitude of re-shoring is $reshoring^{k,1}_{ri,sj} = re^{k,1}_{ri,sj}$; for $r \in \{+- \mid s,i,j\}$ (the host economy), the magnitude of re-shoring is

$$reshoring^{k,1}_{ri,sj} = \frac{\left(\sum\nolimits_{p\in\{-+ \mid s,i,j\}} \left|re^{k,1}_{pi,sj}\right|\right) * re^{k,1}_{ri,sj}}{\sum\nolimits_{q\in\{+- \mid s,i,j\}} \left|re^{k,1}_{qi,sj}\right|}.$$

Furthermore, the 'surplus'

$$\left(\sum\nolimits_{r\in\{+- \mid s,i,j\}} \left|re^{k,1}_{ri,sj}\right| - \sum\nolimits_{r\in\{-+ \mid s,i,j\}} \left|re^{k,1}_{ri,sj}\right|\right)$$

should be recorded as the re-offshoring. Otherwise, if

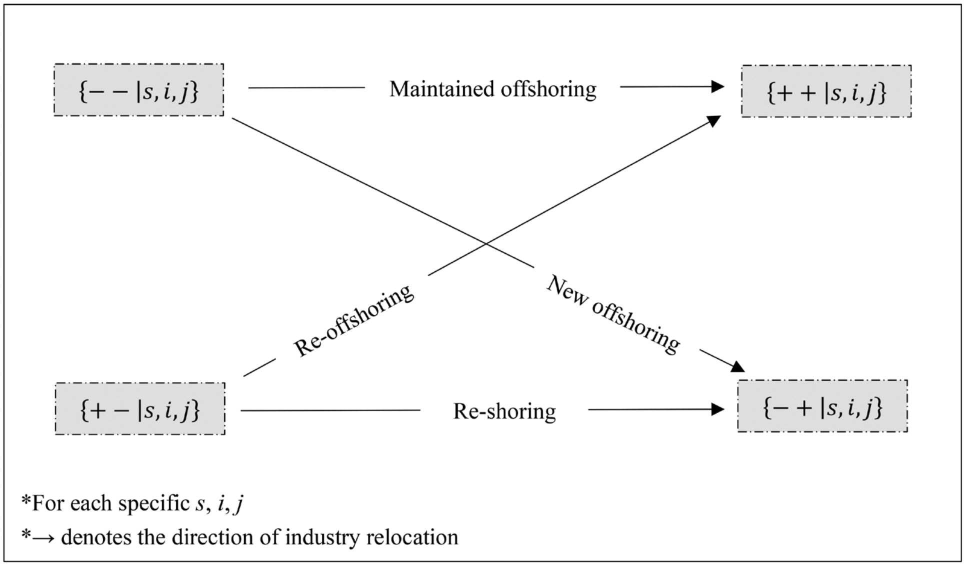

Figure 2. *The relocation patterns in the reporting period.*

$$\sum_{r\in\{-+\ \mid\ s,i,j\}}\left|re^{k,1}_{ri,sj}\right| > \sum_{r\in\{+-\ \mid\ s,i,j\}}\left|re^{k,1}_{ri,sj}\right|,$$

it means the production relocated out from the host economy is less than the production relocated into the home economy. Then, for $r \in \{-+ \mid s,i,j\}$, the magnitude of re-shoring is

$$\text{reshoring}^{k,1}_{ri,sj} = \frac{\left(\sum_{q\in\{+-\ \mid\ s,i,j\}}\left|re^{k,1}_{qi,sj}\right|\right) * re^{k,1}_{ri,sj}}{\sum_{p\in\{-+\ \mid\ s,i,j\}}\left|re^{k,1}_{pi,sj}\right|};$$

for $r \in \{+- \mid s,i,j\}$, the magnitude of re-shoring is $reshoring^{k,1}_{ri,sj} = re^{k,1}_{ri,sj}$. And the 'deficit'

$$\sum_{r\in\{-+\ \mid\ s,i,j\}}\left|re^{k,1}_{ri,sj}\right| - \sum_{r\in\{+-\ \mid\ s,i,j\}}\left|re^{k,1}_{ri,sj}\right|,$$

should be recorded as the new offshoring generated in the reporting period.

Step 4: measure the magnitude of re-offshoring in the reporting period

The re-offshoring means moving the previously offshored production to third economies except home. Thus, it corresponds to the industry relocation from $\{+- \mid s,i,j\}$ to $\{++ \mid s,i,j\}$ (all that to $\{-+ \mid s,i,j\}$ are counted in re-shoring). According to step 3, when

$$\sum_{r\in\{-+\ \mid\ s,i,j\}}\left|re^{k,1}_{ri,sj}\right| \leq \sum_{r\in\{+-\ \mid\ s,i,j\}}\left|re^{k,1}_{ri,sj}\right|,$$

then for $r \in \{++ \mid s,i,j\}$, the magnitude of re-offshoring is

$$reoffshoring^{k,1}_{ri,sj} = \frac{\left(\sum_{q\in\{+-\ \mid\ s,i,j\}}\left|re^{k,1}_{qi,sj}\right| - \sum_{p\in\{-+\ \mid\ s,i,j\}}\left|re^{k,1}_{pi,sj}\right|\right) * re^{k,1}_{ri,sj}}{\sum_{u\in\{++\ \mid\ s,i,j\}}\left|re^{k,1}_{ui,sj}\right|};$$

for $r \in \{+- \mid s,i,j\}$, the magnitude of re-offshoring is $reoffshoring^{k,1}_{ri,sj} = \mathrm{re}^{k,1}_{ri,sj} - reshoring^{k,1}_{ri,sj}$.

Step 5: measure the magnitude of offshoring in the reporting period

There are two kinds of offshoring in the reporting period. The first is the new offshoring generated in the reporting period, which corresponds to the industry relocation from $\{--\mid s,i,j\}$ to $\{-+\mid s,i,j\}$. The second is the offshoring maintained from the benchmark period, which corresponds to the industry relocation from $\{--\mid s,i,j\}$ to $\{++\mid s,i,j\}$. Thus, for $r\in\{++\mid s,i,j\}$, the magnitude of the offshoring is $\mathrm{offshoring}_{ri,sj}^{k,1}=re_{ri,sj}^{k,1}-\mathrm{reoffshoring}_{ri,sj}^{k,1}$; for $r\in\{-+\mid s,i,j\}$, when

$$\sum\nolimits_{r\in\{-+\mid s,i,j\}}\left|re_{ri,sj}^{k,1}\right|>\sum\nolimits_{r\in\{+-\mid s,i,j\}}\left|re_{ri,sj}^{k,1}\right|,$$

the magnitude of the offshoring is

$$\mathit{offshoring}_{ri,sj}^{k,1}=\frac{\left(\sum_{p\in\{-+\mid s,i,j\}}\left|re_{pi,sj}^{k,1}\right|-\sum_{q\in\{+-\mid s,i,j\}}\left|re_{qi,sj}^{k,1}\right|\right)*re_{ri,sj}^{k,1}}{\sum_{p\in\{-+\mid s,i,j\}}\left|re_{pi,sj}^{k,1}\right|};$$

for $r\in\{--\mid s,i,j\}$, the magnitude of the offshoring is $\mathit{offshoring}_{ri,sj}^{k,1}=re_{ri,sj}^{k,1}$. Supplementary Appendix B summarises the equations measuring the magnitude of different relocation patterns.

In summary, the proposed approach has three advantages relative to the existing measurements. First, it is a systematic approach to simultaneously measuring the magnitude of all relocation patterns. Secondly, considering that the advanced economies usually offshore the low-value-added processes while they are more likely to re-shore the high-value-added processes, the value-added re-distribution may bias the magnitude of relocation patterns. Thus, our measurement is from the perspective of production to avoid such bias. Thirdly, the results provide information for the economy (r), industry (i) and process (k) that are involved in different relocation patterns. Thus, it establishes a data foundation for capturing the *process-specific*, *industry-specific* and *country-specific* features in different relocation patterns (for example, a *country-specific* analysis of offshoring can be conducted based on $\sum_i\sum_k\sum_s\sum_j \mathit{offshoring}_{ri,sj}^{k,1}$). In the next section, the paper will empirically measure the magnitude of the three relocation patterns between 2007–2014 based on the proposed approach and test the hypotheses put forward earlier.

Empirical analysis

The empirical analysis relies on the 2016 Release of WIOT (World Input-Output Tables) in the WIOD (World Input-Output Database) database[14] that contains annual time series multi-economy input–output tables covering the time frame from 2000 to 2014. Each WIOT provides the value of transactions among 56 industries in 43 economies plus the 'rest of the world (ROW)' (Timmer et al., 2015; Timmer et al., 2016). The paper will focus on manufacturing, the so-called 'foot-loose' industry (Ge, 2009), to conduct the analysis on production location re-configuration during 2007–2014.

The process-specific analysis

As shown in Table 2, the magnitude of global manufacturing relocation during the period 2007–2014 reached \$5.8 trillion U.S. dollars, of which 56.6% is offshoring (\$3.3 trillion), 28.5% is re-shoring (\$1.7 trillion) and 14.9% is re-offshoring (\$0.9trillion). This result is consistent with the common view that offshoring was still the dominant relocation pattern prior to 2014. In detail, 55.0% of the industry relocation driven by intermediate inputs (*M4M*) is characterised as offshoring (\$1.8 trillion), 30.5% as re-shoring (\$1.0 trillion) and the remainder, 14.6%, is the re-offshoring (\$0.5 trillion). The percentages are almost the same for the industry relocation driven by final products (*F4F*, 55.2%, 29.8% and 15.0% for offshoring, re-shoring and re-offshoring, respectively), indicating that no obvious differences in relocation-pattern-preference exist between the final and intermediate stages of production,[15] thus rejecting hypothesis 1. However, the percentage of offshoring (64.1%) in the indirect intermediates' relocation driven by final products (*F4M*) is evidently higher than that in *F4F*, while the corresponding percentage of re-shoring (20.0%) is evidently lower. This is because the re-shoring was primarily among the high-income economies (see the Economy-specific analysis section). Those high-income economies are deeply involved in the GVC, and their production is usually dependent on the world manufacturing cores, e.g., China, Vietnam, Mexico, etc. Thus, although the final-product production is re-shored, a part of the associated intermediate production may be maintained in those manufacturing cores and thus higher for the percentage of offshoring and lower for re-shoring in the *F4M*.

The industry-specific analysis

When it comes to the manufacturing with different dominant factor inputs, i.e., labour-intensive, capital-intensive and technology-intensive manufacturing, as shown in Figure 3 (Panel A), one can find that the largest effect of the industry relocation during 2007–2014 occurs in technology-intensive manufacturing, followed by capital-intensive manufacturing, two types of industries characterised by a high degree of fragmentation. The relocation-pattern-preference in labour-intensive manufacturing is significantly different from that in capital- or technology-intensive manufacturing. As shown in Figure 3 (Panel B), 66.2% of the industry relocation in labour-intensive manufacturing corresponds to offshoring, which is more than ten percentage points higher than that of capital- (55.1%) or technology-intensive (54.5%) manufacturing. On the other hand, 18.7% of the industry relocation in labour-intensive manufacturing corresponds to re-shoring, which is more than ten percentage points lower than that of capital- (30.6%) or technology-intensive (30.3%) manufacturing. This result confirms hypothesis 2 that, no matter whether expressed in terms of magnitude or percentage, the re-shoring in capital- or technology-intensive manufacturing is more likely to be adopted than that in labour-intensive manufacturing. The most probable explanation is that the re-shoring of capital- or technology-intensive manufacturing is more likely to meet the demand of rebuilding industrial competitiveness in the developed economies, since these two types of industry are more involved in the new generation techniques.

Note that the production technology of a specific industry may vary in different countries. For example, electronics assembly may be assigned to low-wage workers in a developing country, while finished by the auto-production equipment in a developed country. Such production technology would also be switched with the production relocation. Thus, the re-shoring of technology-intensive manufacturing may

Table 2. *The magnitude of each relocation pattern and its percentage in each type of industry relocation during 2007–2014.*

Manufacturing relocation	Magnitude (millions of US$)	Magnitude of each relocation pattern (millions of US$) and its percentage					
		Offshoring	%	Re-shoring	%	Re-offshoring	%
M4M	3,313,285	1,821,041	55.0	1,010,123	30.5	482,121	14.6
F4F	1,511,427	834,115	55.2	449,957	29.8	227,355	15.0
F4M	1,008,444	646,199	64.1	201,753	20.0	160,492	15.9
Total	5,833,156	3,301,354	56.6	1,661,834	28.5	869,968	14.9

M4M denotes the industry relocation driven by intermediate inputs; *F4F* denotes the industry relocation driven by final products; F4M denotes the indirect intermediates' relocation driven by final products.

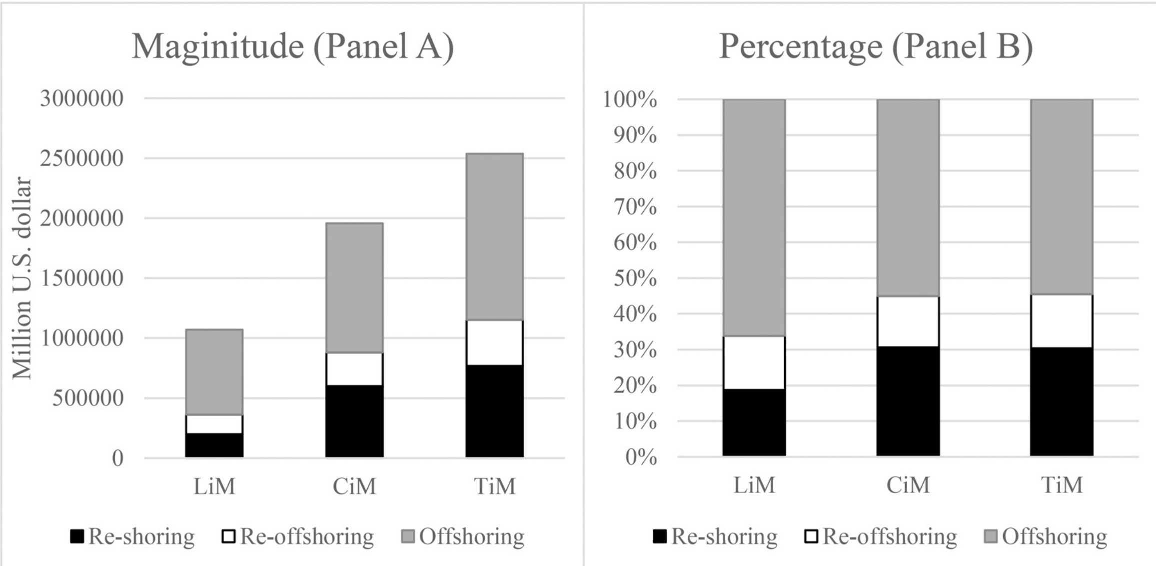

Figure 3. *The magnitude of each relocation pattern and its percentage in manufacturing with different dominant factor inputs.* 1. LiM denotes the Labour-intensive Manufacturing; CiM denotes the Capital-intensive Manufacturing; TiM denotes the Technology-intensive Manufacturing. 2. The classification of industries is presented in Supplementary Appendix C.

also decrease the income of low-wage workers in the host country, while the re-shoring of labour-intensive manufacturing (although it has happened far less often) may not increase the income of low-wage workers in the home country (see examples in Faber, 2020 and Krenz et al., 2021).

At the industry level, as shown in Figure 4 (Panel A), '*Manufacture of computer, electronic and optical products*' (industry 13) has the highest magnitude of both offshoring, re-shoring and re-offshoring. Over the period 2007–2014, 34.2% of its gross production has been relocated, which is the highest among all manufacturing industries. As for the shares of each relocation pattern, as shown in Figure 4 (Panel B), '*Manufacture of basic pharmaceutical products and pharmaceutical preparations*' (industry 8), '*Manufacture of other transport equipment*' (industry 17), '*Manufacture of chemicals and chemical products*' (industry 7), '*Manufacture of machinery and equipment*' (industry 15) and '*Manufacture of motor vehicles, trailers and semi-trailers*' (industry 16) are the industries that have the highest percentage of re-shoring in gross industry relocation. Over the period 2007–2014, 39.8%, 38.0%, 37.1%, 36.1% and 35.9% respectively of their industry relocation was accounted for by re-shoring. This result also supports hypothesis 2 that re-shoring is more likely to happen in capital- or technology-intensive industries. Meanwhile, '*Manufacture of basic pharmaceutical products and pharmaceutical preparations*' (industry 8), '*Manufacture of electrical equipment*' (industry 14) and '*Manufacture of wood and of products of wood and cork, except furniture*' (industry 3) are the industries with the highest percentage of re-offshoring. During 2007–2014, 22.0%, 21.3% and 21.1% respectively of their industry relocation fit into the re-offshoring.

The economy-specific analysis

A specific economy may be the destination of a specific relocation pattern in some cases, and at the same time, the source of the same

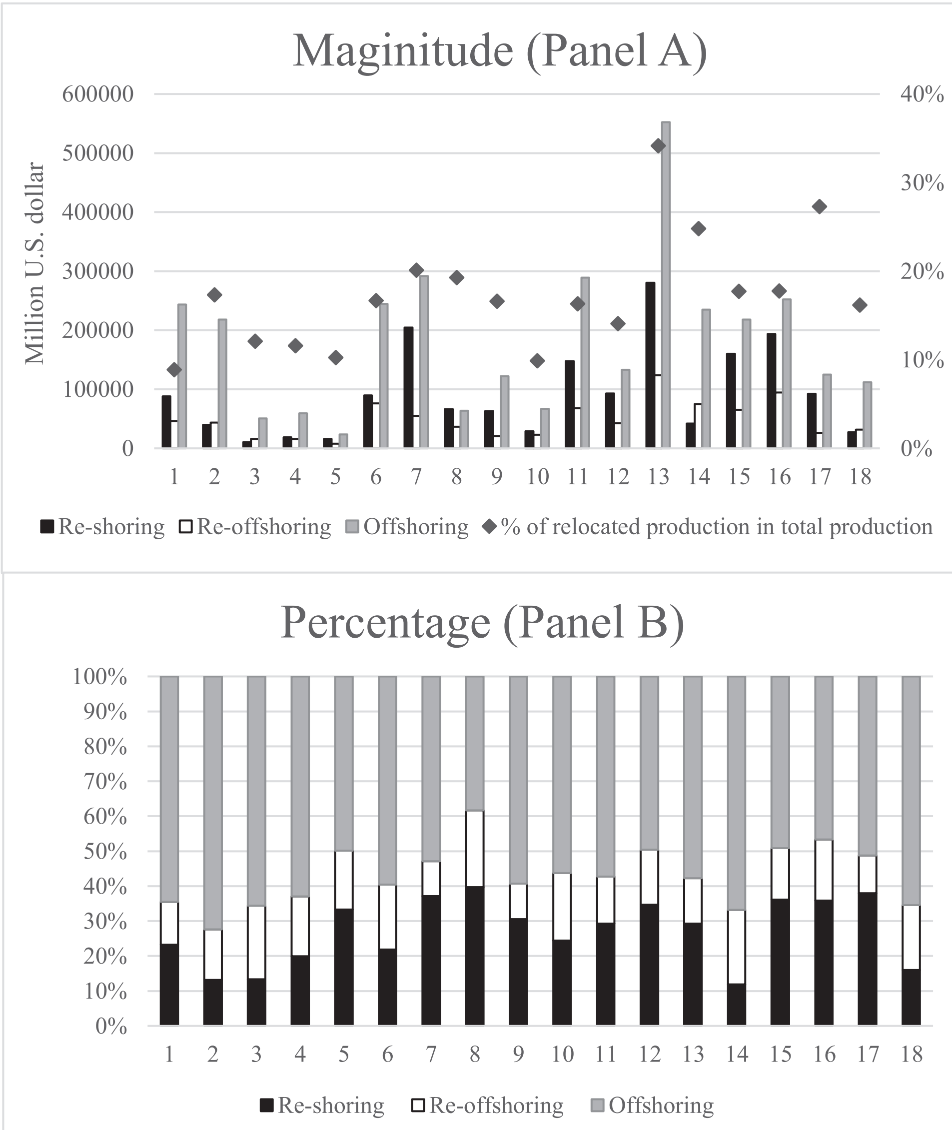

Figure 4. *The magnitude of each relocation pattern and its percentage in different industries.*
(i) The numbers in the X-axis are sectoral index of manufacturing industries, their corresponding names are listed in Supplementary Appendix C. (ii) The industry 1–5 and 18 belong to labour-intensive manufacturing; industry 6–12 belong to capital-intensive manufacturing; and industry 13–17 belong to technology intensive manufacturing.

relocation pattern in the others.[16] Most economies exhibit both relocation directions (in or out) in different relocation patterns, as shown in Figure 5. For offshoring, as shown in Figure 5 (Panel A), China (CHN) maintained its position as the most prominent offshoring destination during period 2007–2014, and the typical developed economies, i.e., the G7 economies, were the major source of offshoring. During this period, 48.5% of the world offshoring relocated to China, and 61.4% of the world offshoring originated from the G7 economies. Considering that offshoring was still the dominant relocation pattern, the general trend that the manufacturing production moves from the developed economies to developing economies (especially China) had not been reversed before 2014.

When it comes to re-shoring, as shown in Figure 5 (Panel B), it might be confusing that China, as a developing economy and the most prominent offshoring destination, has the highest magnitude of re-shoring-in; 38.7% of the world re-shoring moved to China. In fact, this result is because the substitution of domestic for imported materials has been increasingly occurring in China. Looking back to the two decades before the global financial crisis in 2008, China was increasingly participating in the GVC and benefitted significantly from the global offshoring driven by production fragmentation. However, the production processes that moved to China required the associated intermediate inputs that needed to be imported from other countries, and thus, induced the prevalence of 'processing trade' (Chen et al., 2012; Yang et al., 2015) and 'offshored' these intermediates out from China.[17] After experiencing rapid economic growth, China now has the largest industrial system globally with the most complete categories, which enables China to enact the substitution of imported materials with high quality and low price. The increasing substitution of domestic for imported materials in China would push the 're-shoring' of those 'offshored' intermediates back to China. This result is in line with China's increasing trend in domestic content in exports, of which some findings could be found in Kee and Tang (2016), Yang and Yang (2017) and Zhu (2019). For example, Guilhoto et al. (2019) found China exhibited one of the steepest declines in the dependence on foreign materials in its supply chains. Based on OECD TiVA database, they find China's foreign value-added share of manufactured exports decreased about ten percentage points from 2005 to 2015.

Excluding the magnitude of re-shoring to China, one can find that most of the re-shoring happened between the high-income economies. As shown in Figure 5 (Panel B), the magnitude of re-shoring participated by each economy is generally rising with the increase of their corresponding GDP per capita. For example, during the period of study, 38.9% of the world re-shoring was from the G7 economies and 32.6% moved to them (excluding the magnitude to China). This finding confirms hypothesis 3 that the manufacturing production offshored to the high-income economies are more likely to be re-shored, and its explanation is closely related to the results from the industry-level analysis. Since the high-income economies have a clear competitive advantage and are featured prominently as destinations of previous offshoring in the high-end industries, the higher re-shoring probability in the high-end industries leads to a higher re-shoring percentage from the high-income economies.

As for re-offshoring, as shown in Figure 5 (Panel C), China played the most dominant role in the destinations of re-offshoring. During the period of analysis, 48.7% of the world re-offshoring has moved to China. The extraordinary magnitude of offshoring, re-shoring and re-offshoring received by China supports the conclusion from Guilhoto et al. (2019) that the continuous growth of China and its trade volume strongly strengthen its role as a supplier to the world (including China itself).[18] The high-income economies were also the major source of re-offshoring. For example, between 2007 and 2014, 37.9% of the world re-offshoring was from the G7 economies. Thus, the manufacturing production that previously offshored to the high-income economies is much more locationally flexible than the others after the global financial crisis. To sum up, facing the impact of economic recession, the high-income economies prefer to move back the high-end production

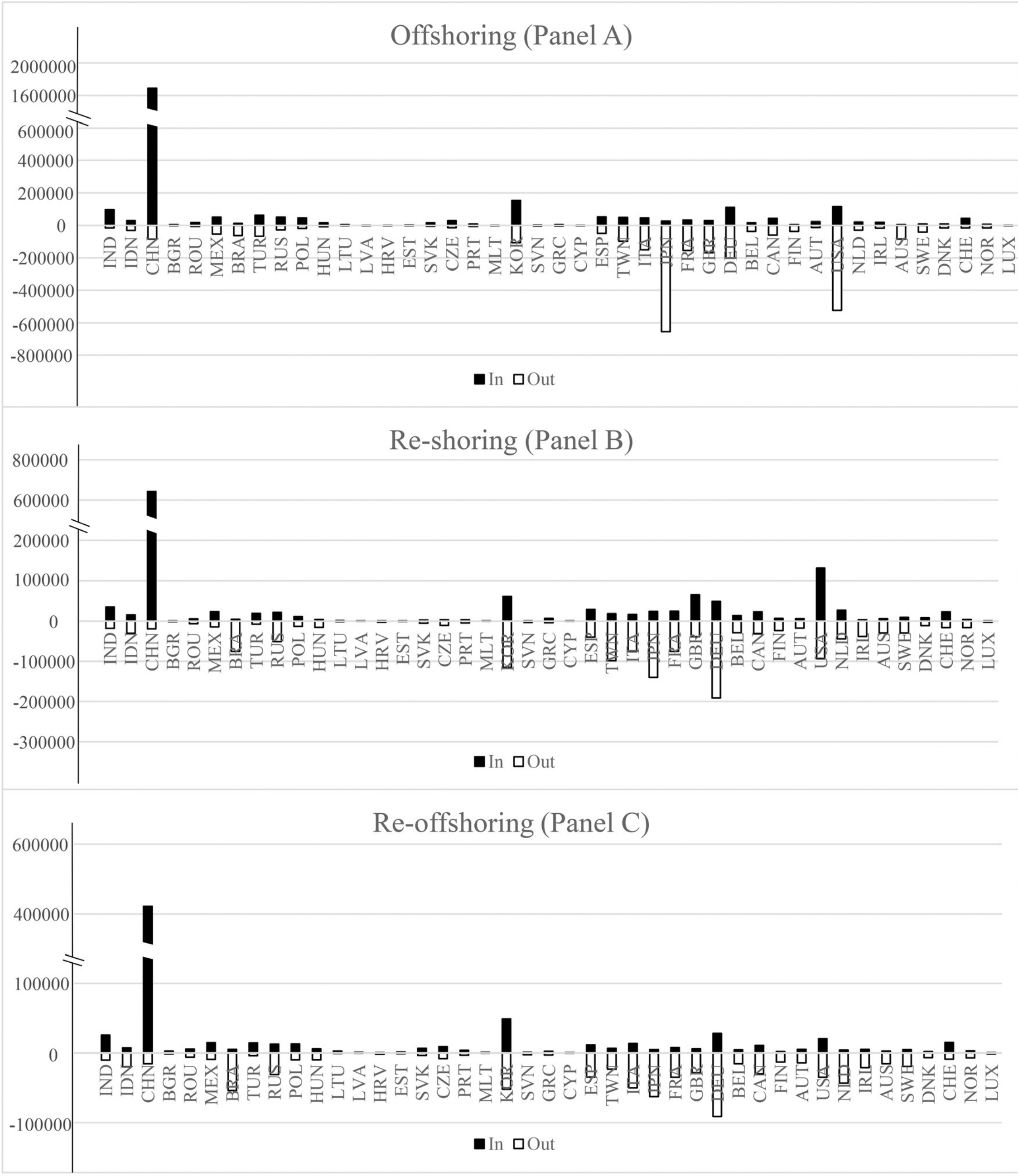

Figure 5. *The magnitude of each relocation pattern in different economies.*
(1) in this figure, 'in' denotes the production relocated into the economy through the corresponding relocation pattern, while 'out' denotes the production relocated out from the economy. In panel A, the black bar ('in') denotes the magnitude of production offshored to the corresponding economy (as the host economy); while the white bar ('out') denotes the magnitude of production offshored out from it (as the home economy). In panel B, the black bar ('in') denotes the magnitude of production re-shored to the corresponding economy (as the home economy); while the white bar ('out') denotes the magnitude of

from other high-income economies for rebuilding their own industrial competitiveness, while, at the same time, retaining the cost advantages of a global fragmented network through the low-end production offshoring or re-offshoring. A summary of locational preference in different relocation patterns is presented in Table 3.

The geography-specific analysis

The longstanding empirical literature on modelling flows using the gravity equation and the postulates of the New Economic Geography have highlighted the significant influence of distance for many economic activities. However, the research on geographical features of the emerging re-shoring is quite limited. To shed some light on this development, the paper estimates the magnitude of re-shoring from different continents to top receiving economies based on the assumption of fixed source proportion of re-shoring.[19] Referring to Figure 5, the top five receiving economies of re-shoring are China, the USA, the UK, South Korea and Germany. As shown in Table 4, 45% and 22% of the re-shoring volume received by China and South Korea respectively is from other Asian economies. It is evidently higher than the percentages for the USA, UK and Germany (14%, 7% and 13% of the re-shoring was from Asian economies, respectively). In contrast, 63% and 60% of the re-shoring magnitude received by the UK and Germany respectively is from other European economies. It is also evidently higher than the percentages for China, the USA and South Korea where, respectively, 27%, 40% and 47% of the re-shoring was from European economies. These results indicate that the geography of re-shoring was prominent for top re-shoring receivers and confirms hypothesis 4 that the re-shoring is more likely to happen with a higher degree of proximity between countries.

Furthermore, the geographic feature of re-shoring is more significant in labour-intensive manufacturing when it comes to high-income economies, although those labour-intensive industries are less likely to be re-shored than the others. As shown in Table 4, for the USA, UK, South Korea and Germany, the percentages of the labour-intensive reshoring from the corresponding located continent in the gross labour-intensive re-shoring magnitude received by those economies are even higher than that in total manufacturing. As an efficient approach to alleviate the problem of unemployment (a serious problem facing high-income economies after the global financial crisis), the re-shoring of labour-intensive manufacturing is more urgent than the others. Thus, the more significant geographic feature in labour-intensive manufacturing re-shoring also supports the finding that the re-shoring is easier to be conducted between the countries with a higher degree of proximity.

In summary, the testing of the hypotheses revealed that:

H1: The offshore production in the final processes of the GVC is more likely to be re-shored than the intermediate stages of production. **Rejected**.

H2: The offshore production of the capital- or technology-intensive manufacturing is more likely to be re-shored than the offshore production of the labour-intensive manufacturing. **Accepted**.

H3: The manufacturing production that was offshored to the high-income countries is

production re-shored out from it (as the host economy). In panel C, the black bar ('in') denotes the magnitude of production re-offshored to the corresponding economy (as the third economy); while the white bar ('out') denotes the magnitude of production re-shored out from it (as the host economy). (2) The Upper letters in the X-axis are economy codes, their corresponding economy names are listed in Supplementary Appendix C. (3) The economies in the X-axis are ascending sorted by their GDP per capita published by the World Bank, while the data of Taiwan (TWN) region is not available. Thus, the authors additionally searched it through Google. (4) The magnitude of 'Rest of World' region is not presented in this figure.

Table 3. *The percentages of economies with different income level in different relocation patterns.*

Relocation patterns		% of economies with different income level		
		High-income economies	China	Others
Offshoring	in	27.1	48.5	24.4
	out	**81.6**	2.7	15.7
Re-shoring	in	35.1	38.7	26.2
	out	**73.6**	1.2	25.3
Re-offshoring	in	29.4	48.7	21.9
	out	**74.4**	1.8	23.8

(i) The **'in'** and **'out'** in this table have the same meaning as that in Figure 5. (ii) The high-income economies are according to the classification of the World bank. While the Taiwan region is also classified as high-income economy since its GDP per capita falls in this range. And the 'Rest of World' is classified in 'Others'. The detail classification of economies is presented in Supplementary Appendix C. (iii) The percentage China is separately presented in this table simply because of its extraordinary magnitude.

more likely to be re-shored or re-offshored. **Accepted**.

H4: Re-shoring would be more likely to happen with the higher degree of proximity between countries. **Accepted**.

Conclusions and discussions

The paper proposes a systematic approach to measuring the magnitude of three competing relocation patterns (i.e., offshoring, re-shoring, re-offshoring) that determines the evolution of global production location. The approach overcomes the shortcomings of the existing measurements and can establish a data foundation for capturing the process-specific, industry-specific and country-specific features in those relocation patterns. Based on this approach and the 2016 Release of WIOD database, the paper uncovers the production location re-configuration during 2007–2014 and verifies the hypotheses drawn from the recent relocation literature.

The empirical results show that, during 2007–2014, 56.6%, 28.5% and 14.9% of the magnitude of global manufacturing relocation correspond to offshoring, re-shoring and re-offshoring, respectively, supporting the common view that offshoring was still the dominant relocation pattern prior to 2014. The industry-specific results confirm that the re-shoring is more likely to be adopted in capital- or technology-intensive manufacturing. The economy-specific results confirm that the manufacturing production previously offshored to the high-income economies is much more locationally flexible after the global financial crisis. To sum up, facing the impact of economic recession, high-income economies prefer to move back the high-end production from other high-income economies for rebuilding their own industrial competitiveness, while, at the same time, retaining the cost advantages of a global fragmented network through the low-end production offshoring or re-offshoring. In addition, the geography-specific results confirm that the re-shoring is more likely to happen with a higher degree of proximity between countries; such a feature is more significant in the labour-intensive re-shoring.

The paper shows that the 2008 global financial crisis had provided a sense of the flexibility for global manufacturing location. Furthermore, given the significant supply chain disruptions caused by the COVID-19 crisis post-2020, further relocations are likely to be accelerated especially now that many countries,

Table 4. *The percentages of re-shoring magnitude from each continent.*

Total manufacturing		China	The USA	The UK	South Korea	Germany
% of the re-shoring was from the economies in	Europe	27	40	**63**	47	**60**
	Asia	**45**	14	7	**22**	13
	Australia	1	1	1	2	0
	North America	8	**14**	9	7	20
	South America	1	3	3	13	3
	Rest of World	19	28	16	9	4
Labour-intensive		China	The USA	The UK	South Korea	Germany
% of the re-shoring was from the economies in	Europe	19	37	**69**	37	**77**
	Asia	27	10	5	**37**	6
	Australia	5	2	0	6	1
	North America	5	**18**	2	3	7
	South America	1	4	4	8	2
	Rest of World	43	29	20	10	8
Capital-intensive		China	The USA	The UK	South Korea	Germany
% of the re-shoring was from the economies in	Europe	26	46	57	44	58
	Asia	56	15	5	25	10
	Australia	1	1	1	1	1
	North America	12	14	15	8	26
	South America	1	4	2	11	3
	Rest of World	4	20	20	12	3
Technology-intensive		China	The USA	The UK	South Korea	Germany
% of the re-shoring was from the economies in	Europe	28	35	68	54	58
	Asia	39	14	13	11	16
	Australia	0	1	1	1	0
	North America	6	11	8	9	19
	South America	0	1	4	20	3
	Rest of World	27	37	6	4	4

The continent in the table denotes the economies listed in WIOT that located in the corresponding continent. For example, Brazil is the only economy in South America that is included in WIOT and thus South America here only refers to Brazil. Other economies located in the corresponding continent but not listed in WIOT are included in the Rest of World.

including the USA, are talking about strategic industries that need to be located domestically. Although the empirical part in this paper covers a period prior to 2014 due to the data availability, the authors believe that our methodology will enhance the toolset for revealing the magnitude of different relocation patterns and help analysts capture a clearer sense of global production location re-configuration. With the development of WIOT compiling framework and forthcoming WIOT in more recent years, the approach proposed by this paper will assist in interpreting the evolution of different relocation patterns and their features after the sequential shocks generated by the UK 'Brexit' crisis, the US–China trade war and the COVID-19 pandemic.

This paper investigates the offshoring, re-shoring and re-offshoring at a macro level and thus it is not possible to view the changes from the perspective of individual firms. This clearly generates some important limitations. First, the sectoral-level data cannot distinguish the different production technology of the same product across different countries and thus cannot observe the switch of production technology associated with production relocation (see Faber, 2020; Krenz et al., 2021). Secondly, some offshoring and re-shoring activities by different firms in a particular period and industry may be cancelled out by each other when using sector-level data. However, we believe that such limitations are derived from the trade-off between the data aggregation level and the need to have extensive coverage. Although the firm-level data provides more detailed information and expresses the individual motivation for the relocation activities, the major disadvantage of firm-level data is that its accessibility and representativeness vary in different regions or for different time periods. Therefore, the firm-level data are usually treated more as anecdotal evidence (De Backer et al., 2016), and thus, not suitable for measuring the magnitude of offshoring, re-shoring and re-offshoring at the macro-level (by country and industry), which is the research objective of our paper. Notwithstanding these data limitations, the paper and the proposed methodology provide a more systematic and clear view of production location re-configuration across the world and by different industries. However, the authors agree with Krenz and Strulik (2021) that micro- and macro- methods on production location re-configuration are not substitutes but important complements.

Supplementary material

Supplementary material is available at *Cambridge Journal of Regions, Economy and Society* online.

Endnotes

[1] The scope of offshoring differs in the different research areas. In the 'supply-chain management' literature, offshoring usually focuses on the multinational enterprises moving their whole or partial production capacity to their overseas subsidiaries, which is closely related to the international investment. While, in the GVC papers, the offshoring also includes changing from domestic suppliers to foreign suppliers (Feenstra and Hanson, 1999). This can be realised by global trade even when no international investment exists and is determined by the dynamic competitive advantages of different economies across the world. In this paper, we adopted the latter definition that has a broader scope.

[2] Although the recent Big-Data techniques may improve the data accessibility, e.g., the Re-shoring Initiative (https://reshorenow.org/) indicated that the re-shoring poised to surge 38% to a record high in 2021 by extracting job announcements data via automated Google search. However, the opaqueness of the data processing would increase concerns about data reliability.

[3] Such preference may be reversed in the re-shoring, as derived by Hypothesis 2.

[4] The Methodology section is focusing on the measurement of production relocation, rather than the mechanism and reasons why such production relocations might take place. A strand of literature has discussed the latter issue based on the theoretical framework, such as Baldwin and Venables (2013), Fujita and Thisse (2013) and Antràs and De Gortari (2020).

[5] The modelling process of the case with more than two economies is similar with that presented in this section. The following notation is used for easier understanding: upper case bold letters are matrices, lower case bold letters are vectors and lower case non-bold letters are scalars. I denotes the identity matrix.

[6] Hereinafter, the subscript i and j denotes the industry sectors.

[7] The hat symbol (^) indicates the diagonalisation of a vector.

[8] In equation (3), by employing the form of Hadamard product, ./ denotes the elementwise division for two matrixes with the same dimensions. For example,

$$\textit{if } C_{tr} = \begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} \textit{ and } C_t^* = \begin{pmatrix} 2 & 3 \\ 4 & 5 \end{pmatrix}, \text{ then,}$$

$$r_{tr} = c_{tr}./c_t^* = \begin{pmatrix} \frac{1}{2} & \frac{2}{3} \\ \frac{3}{4} & \frac{4}{5} \end{pmatrix}.$$

[9] In equation (4), $\circ$ denotes the Hadamard product of elementwise multiplication for two matrixes with the same dimensions.

[10]Note that the vector $\boldsymbol{ff}$ is distinguished from

$$\boldsymbol{f} = \begin{pmatrix} \boldsymbol{f}_{rr} + \boldsymbol{f}_{rs} \\ \boldsymbol{f}_{sr} + \boldsymbol{f}_{ss} \end{pmatrix}$$

The latter is the vector of the final products *produced* in each economy.

[11]This paper sets the period 2000–2007 as the benchmark period and period 2007–2014 as the reporting period since several relevant papers have suggested that offshoring was the most prominent relocation pattern before the financial crisis in 2008. For example, Delis et al. (2019) showed that the increase in re-shoring activity was triggered by the financial crisis beginning around 2008.

[12]The type of change depends on the type of industry relocation. For the industry relocation driven by intermediate inputs ($k = 1$), it corresponds to the change of spatial supply-shares in the intermediates used by industry j, which happens in the production process. For the other two types of industry relocation ($k = 2, 3$), it corresponds to the change of spatial supply-shares in industry j's final products consumed in economy s, which happens in the final consumption side.

[13]Although the measurements can indicate where the production relocates to or where it comes from, unfortunately, it cannot connect the destination and its corresponding origins.

[14]http://www.wiod.org/hom

[15]This result is drawn by the comparison of relocation-pattern-preference only between *M4M* and *F4F*, because these two types of industry relocation happen in an active manner (the producers or consumers change the choice between different suppliers). On the contrary, the indirect intermediates' relocation driven by final products happens in a passive manner, which is dependent on the occurrence of *F4F*.

[16]For example, microchip production may be re-shored from China to the USA by the US-based company, while simultaneously, be re-shored from the USA to Japan by the Japan-based company, then the USA exhibit both the re-shoring-in (in the first case) and the re-shoring-out (in the second case). In our measurements, for each specific r, i, k, there exist some s, j that $offshoring^k_{ri,sj}$ *or* $reshoring^k_{ri,sj}$ *or* $reoffshoring^k_{ri,sj} < 0$. Then it means the industry i's production will be relocated out from the economy r under these drivers (s, j) through the corresponding relocation pattern. For other s, j that $offshoring^k_{ri,sj}$ *or* $reshoring^k_{ri,sj}$ *or* $reoffshoring^k_{ri,sj} > 0$, it means the industry i's production will be relocated into the economy r under these drivers (s, j) through the corresponding relocation pattern.

[17]This kind of offshoring is consistent with the idea of offshoring index by Feenstra and Hanson (1999).

[18]Guilhoto et al. (2019)'s conclusion is draw from an analysis covering the period 2005–2015, which is slightly wider than the period focused by this paper—2007–2014.

[19]The measurements proposed by this paper can measure the magnitude of re-shoring going to or coming from each economy but cannot connect the sources and the destinations. Thus, it is necessary to adopt some assumptions for estimating the magnitude of re-shoring from a specific source to a specific destination. In this paper, we adopted the assumption of fixed source proportion of re-shoring. It means the re-shoring receivers in the same group have the fixed source proportions, which equal the proportions of re-shoring magnitude from each economy in the gross re-shoring magnitude. Such assumption is widely adopted in the input-output literature. The detailed estimation equations are presented in Supplementary Appendix D.

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