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Vertical specialization, global trade and energy consumption for an urban economy: A value added export perspective for Beijing

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ABSTRACT

The facilitation of regional trade has boosted the fragmentation in global supply chain, integrating the production, energy and other ecological factors across the regional boundaries by virtue of vertical specialization. The consequences of this trend on urban energy consumption are firstly analyzed by constructing multiregional input–output table and decomposing the value added export in Beijing. Energy consumption per unit of GDP in Beijing is only half of that per unit of value added after adjusting the export by virtue of decomposition techniques and Beijing displays no obvious advantages in energy usage when considering the value added processes. Energy intensive parts of production are relocated outside the metropolis by the downstream and upstream participation in global areas. The results of value added export for energy consumption reveal that the vertical specialization in this metropolis slashes the amount of energy consumption in the city but raises that in the outside. The unified framework by integration of the value added export and energy consumption in this paper could be extended to other related topics.

1. Introduction

The rapid vertical specialization in global supply chain makes the value added processes in the international trade a hotspot. Cities as the center of economic system and human activities play a crucial role in regional trades and energy consumption characterized by massive flows of goods, services and energy. Given that China has become the largest exporter and the second largest importer in the world (The World Bank, 2012), Beijing, capital of China, could be a typical case to cast light into the urban energy consumption that is driven by the global fragmentation of production process closely correlated with the flows of value added and ecological factors. The magnitude of energy consumption in Chinese urban region has been intensively studied by many authors including Gao et al. (2004) for cities of Yangtze Delta Area, Guo et al. (2012), Chen et al. (2013) and Han et al. (2013) for Beijing, Li and Chen (2013) and Gu et al. (2013) for Nanjing, Xu et al. (2013) for six typical cities in southern China, Shao et al. (2014) for Tianjin and Li et al. (2014) for Macao. Another strand of literature has been successful in identifying the driver forces for energy consumption of cities in the context of metabolic processes (Chen and Chen, 2012; Chen and Yang, 2013; Chen et al., 2014; Feng et al., 2013; Su et al., 2012, 2013a,b) and ecological footprint (Chen et al., 2007; Dai et al., 2012; Yang and Chen, 2014) for regional studies. In contrast to previous researches, limited studies could be found accentuating the effects of vertical specialization in global supply chain on energy consumption at city level.

Multiregional input–output (MRIO) model originally conceived for national-wide application (Leontief, 1941) has been extended to illustrate the interdependence among different sectors in economies (Miller and Blair, 2009). With the globalization of commodity supply chains and the growing concerns of interactions for a set of macroeconomic and environmental variables including trade, emission and pollutants on the globe, the MRIO model offers a comprehensive, versatile and compatible approach to analyze the relationship between economic activities and ecosystem (Weidmann et al., 2011). For different aims on environmental and ecological issues, MRIO model that is combined with other techniques such as regression (Chung, 2012) and life-cycle assessment (Chang et al., 2010), is widely applied for calculating Chinese greenhouse gas emission and resources use (Chen and Zhang, 2010), embodied carbon dioxide emission at supra-national

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scale (Chen and Chen, 2011b), and Greenhouse gas emissions in the world (Chen and Chen, 2011a), Chinese regional energy use (Zhang et al., 2013), water usage in the global economy (Chen and Chen, 2013), carbon emission in trade (Su et al., 2013a,b; Su and Ang, 2014) and health impacts of PM2.5 carbonaceous aerosols in Asia (Takahashi et al., 2014).

The vital importance of production fragmentation across countries and regions is well recognized and has gone through abundant investigation recently (Athukorala and Yamashita, 2006; Baldwin and Robert-Nicoud, 2014). The global value added trade brings about fundamental changes concomitant with vertical intra-industry trade, vertical specialization or the use of imported inputs to produce goods that are then exported in the international trade structure (Yoshida, 2013). The supply chain division inevitably leads to inaccuracy of traditional statistics that is vulnerable to double accounting and is incapable to identify the original region where value added engenders (Johnson and Noguera, 2012; Koopman et al., 2014).

Ecological system is characterized by more complexity and mutuality in the context of production fragmentation in world trade networks. As a result of supply chain division, the ecological factors such as labor force and energy are flowing frequent and the interactions between regions have constantly showed an intensified trend. Identifying the linkage among economic activities and the utilization of ecological factors on a global scale becomes essential component of ecological analysis. A number of measures are proposed to evaluate the contribution of local or domestic production in the global supply chain. Hummels et al. (2001) assumes that the imported inputs are used fairly in production for domestic demand and intermediates for export to estimate the degree of vertical specialization. Daudin et al. (2011) allocates the value added to all the countries involved in the production of final goods to construct a value added export measure called $VS1^*$. Johnson and Noguera (2012) allow for two-way trade in intermediates to improve the methodology proposed by Hummels et al. (2001). Koopman et al. (2014) generalize the aforementioned measures and decompose the MRIO tables into separate subsets for wide perception into the processes of production and trade to assess the degree of vertical specialization. Their study provide a unified framework for identifying the different components in the related literature and splitting the double-counted terms from the traditional trade statistics, and herein could be extended to energy and ecological issues.

The aim of this paper is to provide a unified framework integrating the value added export and energy utilization for urban study and to evaluate the consequences of downstream and upstream participation for vertical specialization in global supply chain in context of Beijing energy consumption. The article is organized as follows. Section 2 describes the data sources and the methodology for construction of multiregional input–output model and decomposition of the value added export. Section 3 presents the results generated by analysis of export value-added decomposition, urban energy assessment, energy intensity reevaluation and vertical specialization. Section 4 states the concluding remarks.

2. Methodology and data sources

2.1. Multiregional input–output model

Several methods for constructing MRIO table depended on the different assumptions of data structure and the availability of data sources have been developed (Riefler and Tiebout, 1970; Polenske, 1980, 2004). The most widely applied approach for MRIO table construction is proposed by Chenery (1953) and Moses (1955), on assumption that trade flows between regions are only determined by original regions and destinations. Let z_i^{rs} be the trade flow of products in the sector i from region r to region s, T_i^s be the sum of products in the sector i transported into region s, the interregional trade coefficient c_i^{rs} could be calculated as:

$$c_i^{rs} = \frac{z_i^{rs}}{T_i^s} \tag{1}$$

where $T_i^s = \sum_r z_i^{rs}$. For each export destination pair, a diagonal matrix whose elements clarify the ratio of the total amount of each good used in region s that comes from region r, could be defined as:

$$\hat{c}^{rs} = \begin{pmatrix} c_1^{rs} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & c_n^{rs} \end{pmatrix} \tag{2}$$

In this paper, three regions, i.e., Beijing, the Rest of China (ROC) and the Rest of the World (ROW), are taken into account. Let

$$C = \begin{pmatrix} \hat{c}^{11} \hat{c}^{12} \hat{c}^{13} \\ \hat{c}^{21} \hat{c}^{22} \hat{c}^{23} \\ \hat{c}^{31} \hat{c}^{32} \hat{c}^{33} \end{pmatrix} \tag{3}$$

and

$$A = \begin{pmatrix} A^1 & 0 & 0 \\ 0 & A^2 & 0 \\ 0 & 0 & A^3 \end{pmatrix} \tag{4}$$

where A^s is the regional input–output technical coefficient matrix for region s ($s = 1, 2, 3$). The MRIO table for Beijing, ROC and ROW could be obtained as:

$$X = CAX + CF \tag{5}$$

where X and F are the vectors of total sectoral output and final demand respectively.

2.2. Value added decomposition for export

The intrinsic pattern rooted in the value added analysis spits the export contents into reasonable parts and attributes each part into different origins. According to Koopman et al. (2014), the gross export for region s could be broken down into nine components affiliated to three categories, as shown in Eq. (6):

$$\begin{aligned} u\hat{E_{S^*}} = & \left\{ V_S \sum_{r\neq s}^{G} B_{ss} \hat{Y_{sr}} + V_S \sum_{r\neq s}^{G} B_{sr} \hat{Y_{rr}} + V_S \sum_{r\neq s}^{G} \sum_{t\neq s,r}^{G} B_{sr} \hat{Y_{rt}} \right\} \\ & + \left\{ V_S \sum_{r\neq s}^{G} B_{sr} \hat{Y_{rs}} + V_S \sum_{r\neq s}^{G} B_{sr} A_{rs} (I - A_{ss})^{-1} \hat{Y_{ss}} + V_S \sum_{r\neq s}^{G} B_{sr} A_{rs} (I - A_{ss})^{-1} \hat{E_{S^*}} \right\} \\ & + \left\{ \sum_{t\neq s}^{G} \sum_{r\neq s}^{G} V_t B_{ts} \hat{Y_{sr}} + \sum_{t\neq s}^{G} \sum_{r\neq s}^{G} V_t B_{ts} A_{sr} (I - A_{rr})^{-1} \hat{Y_{rr}} + \sum_{t\neq s}^{G} V_t B_{ts} \sum_{r\neq s}^{G} A_{sr} (I - A_{rr})^{-1} \hat{E_{r^*}} \right\} \end{aligned} \tag{6}$$

where u is a unity vector, V_s represents the vector of direct value-added coefficient for region s, E_{s*} is the total export from region s to the other regions, Y_{sr} is the final demand in Country s for the final good produced in Country r, A_{sr} and B_{sr} are respectively defined as a block matrix of input–output coefficient and a submatrix of Leotief inverse matrix $B = (I - CA)^{-1}$ in MRIO table, and the hat ^ signifies diagonal for sectoral analysis. The sum of the first three components is the value added export, while that of the second three components is the domestic content in intermediate exports that finally returns home ($VS1^*$) and that of the last three components equals foreign contents. The sum of the previous two stands for domestic content in gross export. Let ε_s be the ratio vector of energy consumption to value added in region s. The energy consumption related to value added export EE_{VT} could be calculated as: