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An emergy and decomposition assessment of China-Japan trade: Driving forces and environmental imbalance

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ABSTRACT

With the robust development of economic globalization, international trade should be fairly conducted in order to strengthen the relations among different nations. Currently, due to different resource endowments and trade policies, different nations face different resources and environmental challenges. Previous studies suggested that even when trade seems balanced in monetary terms, it may be unequal in terms of resources exchanges due to different purchasing power of national currencies. As such, imbalance also exist in terms of environmental quality of traded resources and related environmental costs and emissions, such as embodied energy, water, land, carbon, ecosystem services. Under such circumstances, it is necessary and urgent to identify environmental imbalance of international trade and seek appropriate tools so that more balanced and fairer trade among nations can be implemented. This study investigates the quality of resource flows exchanged between China and Japan during the period 2000–2012. Emergy accounting, a well-established environmental accounting method, is used in this study to quantify the environmental work (past and present ecosystem services) embodied in traded resources. Within a broader emergy-based bio-physical perspective, a Logarithmic Mean Divisia Index (LMDI) decomposition approach is applied to identify the driving forces that affect the evolution of import-export resources balance in the investigated period. LMDI decomposes the driving forces into three factors: (a) scale factor, which depends on the total export volume; (b) technology factor, which depends on the emergy intensity of trade (emergy of traded resources); and (c) structural factor, which depends on the trade structure (mix of exchanged commodities). Results show that China was a net emergy exporter in the years 2000 and 2005, with figures of 7.46E+22 sej/yr and 5.76E+21 sej/yr, respectively, but was a net importer in the years 2008 and 2012, with imported emergy figures of 8.82E+22 sej/yr and 2.43E+23 sej/yr, respectively. Scale and technology factors are the most significant drivers to promote China-Japan trade from an emergy point of view (i.e. from the point of view of environmental quality assessment), while the influence of structural factor was relatively marginal. Trade imbalance and lack of focus on environmental value of resources cannot be the basis for stable economic relations with partner countries, which calls for compensation measures in money or resource terms. This study, by investigating the sustainability of China-Japan international trade, also suggests a methodological approach to increase worldwide trade stability and fairness.

1. Introduction

With the rapid development of economic globalization, the connections between different countries are becoming stronger. Particularly, international trade plays a significant role by allowing all kinds of resource flows exchanges and redistributions (such as energy, materials, labor, money and environmental services) according to different requirements of different countries (Jomo and Rudiger, 2009; Lenzen et al., 2012). Economic growth and

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resources demand not only inevitably intensify resource use and environmental impacts globally, but also cause resources and environmental costs shifting among different countries (Arrow et al., 1995; Arto et al., 2014; Muradian and Martinez-Alier, 2001; Yu et al., 2014). Due to market failures, monetary terms cannot fully capture the complexity of the actual exchanges of resources and environmental flows in trade, and unfair exchanges of embodied resources (energy, materials, land, labor, environmental services) may be hidden in the accounting, even in cases where trade is balanced in monetary terms (Andersson and Lindroth, 2001; Giljum and Eisenmenger, 2004; Rice, 2007; Wackernagel and Rees, 1997). Therefore, more comprehensive indicators that complement market-based economic values need to be implemented for equitable trade policy-making and international stability.

After China entered the World Trade Organization (WTO) in 2001, China's foreign trade has experienced unprecedented growth and made primary contribution to the economic development (WB, 2014). However, the rapid trade development brought many challenges, such as resources depletion and corresponding environmental emissions (Fu et al., 2007; Liu et al., 2015). Previous published research outcomes uncovered that China was a net virtual water, virtual land, and also embodied emissions exporting country through its foreign trade (Minx et al., 2011; Mol, 2011; Peters et al., 2011; Yu et al., 2013; Zhang et al., 2011). Therefore, it is urgent to explore the real gains or losses related to economic, resource and environmental balance of China's foreign trade. The aim of such an investigation is not to stop free trade, but to prepare suitable policies and international agreements that foresee suitable compensation measures in case of evident imbalance of resource exchanges. Emergy accounting method and its supply-side value perspective are used in this study to complement the conventional monetary accounting procedures. Different from other methods quantifying the trade imbalance from environmental point of view, such as Input–Output Analysis (IOA) and Ecological Footprint (EF), EMA provides a global estimation of the total biosphere work supporting natural and human-made systems and helps understand the overall interactions between economic processes and environmental dynamics (Ulgiati and Brown, 2012) so that a more comprehensive trade assessment can be achieved.

The China-Japan trade experienced rapid development over the past four decades. Since the two countries established diplomatic relations in 1972, especially after China's entrance to the World Trade Organization (WTO) in 2001, the economic interdependence of the two countries is becoming closer (JETRO, 2015). Table 1 shows the trends of China-Japan trade from 2000 to 2012. The total trade volume increased by about 299%, with the imported volume increased by about 332%, and the export volume increased by about 266%. Trade ratios in monetary terms for China (money spent for imports/money received for exports) were 0.99, 1.20, 1.29 and 1.17, in 2000, 2005, 2008 and 2012, respectively. These ratios mean that China spent more money for importing goods from Japan after 2000.

Another key feature of China-Japan trade is that China mainly exported energy commodities to Japan in the early 2000s, while Japan exported machinery products and equipment to China at the same period. However, with the rapid development of the Chinese economy, China began to export low-value added machinery products to Japan in recent years (Marukawa, 2012). Such a trade structure change indicates that resource flows between the two countries experienced dynamic changes and deserve more policy considerations.

In this study, China-Japan trade between 2000 and 2012 is investigated. Previous studies on China-Japan trade, highlighted embodied energy or emissions in traded commodities (Dong et al., 2010; Wu et al., 2016; Zhao et al., 2015), but to the best of our knowledge trade issues have not been analyzed from a biosphere point of view (biosphere support, natural capital extraction, ecosystem services, renewability). Under such a circumstance, this study aims to fill this gap. It should be clearly understood that trade relations where value of commodities is not sufficiently rooted in their relation with biosphere dynamics (i.e. the time and patterns of natural capital generation by nature as well as the extent ecosystem services support social and economic processes) cannot be stable over time, in that resources may be used up too quickly, inefficiently and without adequate matching of resource quality to use. In so doing, cleaner production and consumption processes are not the main resource use modality so that increased and cheaper trade only leads to faster resource degradation and depletion.

Moreover, in order to identify the driving forces of promoting China-Japan trade, a decomposition analysis approach is applied. Although decomposition analysis was previously used to explore the key factors in emergy studies of region or specific production systems (Ghisellini et al., 2014; Zhang et al., 2014; Zucaro et al., 2014), no peer reviewed publication has combined emergy accounting with decomposition analysis to investigate trade issues between China and Japan. Consequently, this paper aims at investigating resource flows and driving forces of China-Japan trade so that a biophysical methodological approach for trade sustainability assessment can be tested. All in all, this study explores emergy accounting for identifying imbalance of resource exchanges from the biosphere point of view (biosphere support, ecosystem services, renewability), and complements the conventional monetary accounting procedures; besides that, after identifying the driving factors of resources exchange within China-Japan trade, implements for equitable trade policy-making and international stability are proposed.

This paper is structured as follows. After this introduction section, Section 2 presents research methods, including a short description of China-Japan trade, a detailed introduction of emergy accounting and decomposition analysis, as well as data sources used in this study. Section 3 presents the research results. Section 4 discusses related policy implications. Section 5 concludes the whole paper.

2. Methods and data

2.1. Emergy accounting approach

Emergy accounting (EMA) is a measure of environmental work displayed by the biosphere to generate resources and ecosystem services, and quantify energy, materials, labor and money investments within a process (Brown and Ulgiati, 2011; Geng et al., 2013; Lou and Ulgiati, 2013; Odum, 1996; Tian et al., 2016). By applying emergy accounting, it is possible to quantify how much environmental support is needed to generate a unit (and hence the totality) of a product flow or service or economic wealth within a country (Tian et al., 2016). By definition, emergy is the available energy of one kind (in general of the solar kind) required directly or indirectly to make a product or provide a service (Odum, 1996). The emergy concept of cumulative embodiment over a product supply chain supports the idea that something has a value according to what was invested into making it. In order to quantify the cumulative investment of solar equivalent, available energy, emergy accounting converts different energy and mass inflows to a system or process into a common basis (solar equivalent Joules, or solar emjoules, sej). The added value lies in its ability to include in the calculation the time embodied in resources (time for their generation by biosphere processes), the renewable resources that support ecosystem services even if not directly captured by humans through technological devices, the indirect environmental support