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Uncovering resource losses and gains in China's foreign trade

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ABSTRACT

Natural resource storages and flows play an important role in economic and social processes. In this paper we explore the trade of primary commodities between China and its main trade partners during the years 2000 and 2008. Emergy accounting is used to assess the environmental support associated with the resources exchanged. Mass, emergy and financial capital export-to-import ratios confirm that economy-level trade advantages should not just rely on capital flow. A holistic evaluation of the trade process, including resource environmental value should be performed to identify trade balance and stability. Results show that while China's imports monetary value is much larger than exports monetary value, China receives more emergy (environmental support) in trade than it gives; benefiting from the ability of primary resources to drive its economy. Developed economies, characterized by a low Emergy-to-Money-Ratio, gain more from trade of primary commodities with China. Developing and underdeveloped economies, with higher Emergy-to-Money-Ratio, lose in the environmental support balance to China, indicating the existence of a potentially unsustainable trade imbalance.

1. Introduction

An economy's wealth resides in its resource base (Brown and Ulgiati, 2011). Economies and societies rely on natural resources, such as sunlight, water, land and forests, and social resources such as labor and information (Behrens et al., 2007; Dong et al., 2014). Primary commodities, which are resources directly taken from nature and only slightly processed by humans, are the base of human daily life (Foley et al., 2005; Brown and Ulgiati, 2011). Increased globalization and international trade have accelerated primary commodity flows between countries. Primary commodity exchanges, especially inequitable exchanges, have historically caused numerous challenges and conflicts between developed and developing countries, limiting long term sustainability (Holdren, 1991, 2008; Klare, 2004; Shui and Harriss, 2006).

Economic monetary values are unable to fully capture the environmental services and natural capital embodied in traded goods (Geng et al., 2017; Zhang et al., 2017). Monetary flows management typically under-invest in maintaining natural capital, even when it is possible. Monetary evaluations are appropriate at a market level, where money pays labor for resource extraction, processing and delivery; and prices are affected by scarcity and willingness to pay. Monetary valuation does not account for or underestimates nature's work for resource generation over time, which is an important aspect of resource value. In addition, it is worth mentioning that when a resource requires a large biosphere investment for its generation and delivery, its value from the supply side is huge and makes the resource hardly replaceable, no matter the most often unstable monetary value attributed by the market dynamics. (Behrens et al., 2007; Geng et al., 2013). In light of these considerations, conventional trade assessments and international balances of payments need integration with biophysical assessments in order to understand the sustainability and fairness of trade transactions.

So far, expanding the evaluation of international trade beyond monetary flows focused on either environmental pollution or direct and indirect resource availability. Calculated environmental indicators include airborne emissions such as carbon, methane, sulfur dioxide, mercury, ozone, or particulate matter (Davis et al., 2011;

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Caro et al., 2014; Deng et al., 2016; Li, 2016; Román et al., 2016; Zhang et al., 2017). Embodied resources indicators include energy, water, land, materials, labor, biodiversity and biosphere work (Xu et al., 2009; Bruckner et al., 2012; Lenzen et al., 2012; Hoekstra and Mekonnen, 2012; Qiang et al., 2013; Cortésborda et al., 2015; Geng et al., 2017).

A number of methods have been used to evaluate trade and environment relationships, including Input-Output Analysis (IOA), Material Flows Analysis (MFA), Ecological Footprint (EF) and EMergy Accounting (EMA). IOA is mainly used to account for interdependencies of economic sectors based on sectorial monetary transaction data. Especially, the Environmentally-extended IO (EEIO) could identify both direct and indirect environmental burdens from a consumption perspective (Wiedmann et al., 2007). A limitation of IO Analysis is that the information is usually available only on macro or industrial scales and updates of IO tables are not constant. Iit is not suitable at micro levels due to a lack of data availability (Dong et al., 2016). MFA is used to quantify and monitor human use of natural resources. MFA uses mass units to measure physical flows in the economy, but not all mass units have the same quality. In addition, MFA does not consider the environmental impact of resource exploitation, as well as resource input characteristics in the evaluation. EF helps value environmental carrying capacity of nations and can be easily understood by the popular press, general public, and policy makers (Wackernagel et al., 2006). However, it is often criticized for inaccuracy and variability, for not integrating technology improvement, and also for its limited boundary sets (Geng et al., 2013).

Among these assessment methods, the emergy accounting approach (Odum, 1996) has, to-date, received relatively less attention as a policy support tool. This method accounts for the direct and indirect environmental support provided by nature for resource generation and processing. It can be used to estimate the environmental quality (production effort by nature) of resources supporting economies. It has been used to identify specific aspects of trade such as bilateral trade between China-Japan (Tian et al., 2016), China-USA (Geng et al., 2017), and China-Africa (Huang et al., 2017). It has also been used to investigate regional disparity in international trade in Chinese provinces (Tian et al., 2017), and trade of agricultural commodities by Argentina (Rotolo et al., 2018). However, multilateral trade evaluations are still lacking, which can provide a more holistic picture on complicated and interlinked trade relations.

Under such a circumstance, this study applies an emergy accounting approach (Odum, 1996; Geng et al., 2013) to assess the environmental values of primary commodity flows in trade by employing the case of China-the rest of the world trade so that a complete picture on environmental “wealth” transferred among trade partners can be presented. It seeks to clarify and address a number of issues: (1) How are resources exchanged internationally? (2) What are the true costs and benefits of these regional flows? (3) Are there unequal exchanges in these trade relations? (4) What are the policy and institutional implications of these findings? The whole paper is organized as below. After this introduction section, section 2 depicts research methods and data source. Section 3 presents research results. Section 4 discusses policy implications. Finally, section 5 draws research conclusions.

2. Methods and data sources

2.1. Emergy accounting approach (EMA)

EMA defines a “supply system of value” (Tilley and Brown, 2006), i.e. a biophysical approach to estimate the contribution of nature to economic activity. Emergy is a systems-oriented concept to assess the environmental quality of energy, materials, labor and money investments in systems. Emergy is defined as the available energy (exergy) of the same form, typically solar energy, required directly and indirectly to make a product or provide a service (Odum, 1996). In so doing emergy accounts for the biosphere's environmental work to generate resources and ecosystem services across space and time, and also provides an environmental estimate of human-dominated processes for activities such as extraction and refining (Brown and Ulgiati, 2001, 2004). In emergy assessments, available energy and material resources inputs supporting a system are converted into solar emergy equivalents by multiplying their raw amounts by a suitable Unit Emergy Value (UEV). UEVs are an indirect measure of the total environmental support (production cost) needed to generate a unit of product flow or storage over time (Odum, 1996; Brown and Ulgiati, 2004).

Emergy can be used to determine international trade imbalances, if any, beyond claimed monetary terms of trade equity, highlighting the uncompensated appropriation of natural capital, generation time, ecosystem services, and technological and social information (Brown and Ulgiati, 2001). In emergy trade assessment, EMR (Emergy-to-Money Ratio) is an important country specific parameter. It is the ratio of annual emergy used within a country's economy to its annual GDP and reflects the amount of resources needed to generate one unit of monetary outcome (Table S1 in Supporting Information-SI) (Odum, 1996). It is a measure of the efficiency of the economic process in converting resources into monetary wealth. In general, industrialized countries have low EMR due to high monetary circulation, while developing countries have high EMR due to low monetary circulation, therefore, the amount of resources needed to generate one currency unit are different. Fig. 1 shows that trade flows apparently balanced in monetary terms may have different features when the embodied environmental value is considered.

Monetary flows are standard international trade accounting measures. Economically, a country benefits from trade if the export monetary value exceeds imports’ monetary value. A shift to biophysical flow and benefits accounting may provide a different perspective from pure monetary valuation flows (Ulgiati et al., 2011). It is important to highlight that while monetary flows depend on market dynamics and therefore may change over time, biophysical flows capture a number of characteristics of traded resources that are more likely to remain constant and therefore require longer term decision making strategies.

In addition, there is another aspect associated to commodity trade that needs elaboration. Each traded resource or commodity is described by two flows. One flow is the emergy of the raw material, which is its production cost over the entire supply chain from resource generation by nature to processing and final delivery by humans. The other flow is the emergy of Labor and Services (L&S, Table S1). Labor includes the direct human activity performed within the system's boundaries. Service include the indirect activity related to the infrastructure and the indirect labor chain that make the process possible at the larger scale of the economy. Emergy embodied in L&S takes into account the resource investment in know-how, education, training and infrastructure (Ulgiati and Brown, 2014).

For the purpose of the present study, dealing with trade among nations, only Services (S) are included. This study's statistical data provide raw amounts of traded resources and their monetary prices at the country's border, i.e. when resources are transferred and purchased. The labor invested in this transfer is indirect Labor. Direct Labor arises when the imported resource is further processed within the importing country. Since this study focuses on the exchange of resources crossing country borders, only services