

# ***THE PATTERN OF INTERNATIONAL EMBODIED ENERGY FLOW***

Xiaoqi Sun, School of Humanities and Economic Management, China University of Geosciences (Beijing), +86  
1082322073, sunxiaoqi@cugb.edu.cn

Haizhong An, School of Humanities and Economic Management, China University of Geosciences (Beijing), +86  
1082323783, ahz369@163.com

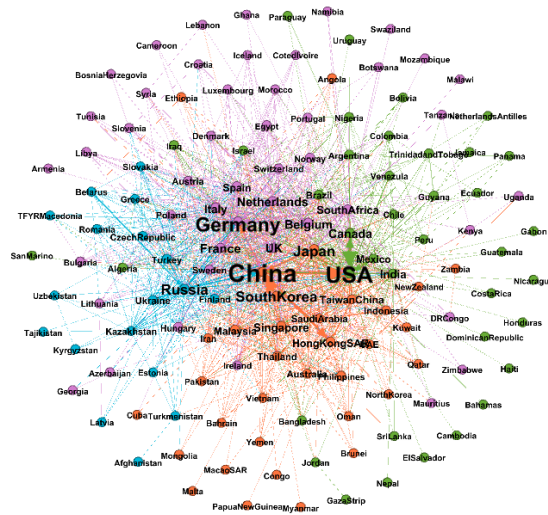
## **Overview**

With the decrease of transportation cost and communication cost, standardized production, and push of free trade policy, the division of labor gives rise to the spatial fragmentation of production. Energy is the basic input to the production, which means that there is energy embodied the semi-finished goods and finished goods. Embodied energy is defined as the sum of direct and indirect energy consumed to produce the goods or services (Brown and Herendeen, 1996; Bullard and Herendeen, 1975; Sun et al., 2016; Chen and Wu, 2017). To see the shift of energy burden caused by the spatial fragmentation of production, this paper investigates the pattern of embodied energy flow between countries. The pattern is defined here as the flow direction, distribution, and the structure of the embodied energy flow between countries.

Using environmental input-output analysis, the most widely used tool in this field, previous studies analysed the embodied energy flow at three scales from two perspectives. From the geographical perspective, the embodied energy flow analyses deal with the flow between geographical units, say, provincial or state units within a country, nations, supranational units. From the industrial perspective, the embodied energy flow analyses focus on the flow between industrial sectors at different levels. This paper belongs to the geographical perspective at the global scale, which is not fully explored currently and thus is our first contribution to the literature.

Our second contribution to the literature is that we combine the environmental input-output analysis with network analysis and study the structure of the international embodied energy flow. Using the nations as nodes, and the embodied energy trade connections as edges, this study constructs an embodied energy flow network model, see Fig. 1. Through the network model, we explore the structure of international embodied energy flow by modularity, average clustering coefficients and average path length. Moreover, we identify the different roles played by the countries in the international embodied energy flow network. Lastly, we discover the flow distribution among countries.

The rest of this paper is organized as follows: data and methodologies are presented in the section 2. Empirical results will be given in the section 3, followed by discussions in the section 4. The last part is our conclusions.



**Fig. 1 International embodied energy flow network**

## Methods

- Step 1: Account the embodied energy flow between countries with environmental input-output data from Eora
- Step 2: Construct the international embodied energy flow network model;
- Step 3: Analyze the flow directions of international embodied energy flow;
- Step 4: Analyze the flow distribution among countries;
- Step 5: Analyze the structure of international embodied energy flow network and identify the critical countries in the network.

## Results

Firstly, Mainland of China, USA, Germany, Russia, and South Korea are the main exporters of embodied energy, which is totally from the direct energy exporters.

Secondly, USA, Mainland of China, Germany, Japan, and UK are the main importers of embodied energy.

Thirdly, the flow distribution among countries follow by the power law.

Lastly, the international embodied energy flow network displays a small world property.

## Conclusions

In this paper, we study the pattern of international embodied energy flow from the geographical perspective. Combining the environmental input-output analysis with network theory, this study constructs an international embodied energy flow network model, followed by the empirical study with Eora data in 2013. The main conclusions are as follows. Mainland of China, USA, Germany, Russia, and South Korea are the main exporters of embodied energy, while USA, Mainland of China, Germany, Japan, and UK are the main importers. Secondly, the flow between countries concentrates in few embodied energy trades. Thirdly, the disruption in one country can lead to systemic disruption of embodied energy flow because of the existence of small world property and power law in the international embodied energy flow network.

## References

- Brown M. T., Herendeen R. Embodied energy analysis and energy analysis: A comparative view. *Ecological Economics*, 1996, 19: 219-235.
- Bullard C. W., Herendeen R. The energy cost of goods and services. *Energy Policy*, 1975, 3: 268-278.

Sun X. Q, An H. Z, Gao X. Y., et al. Indirect energy flow between industrial sectors in China: A complex network approach. *Energy*, 2016, 94: 195-205.

Chen G. Q., Wu X. F. Energy overview for globalized world economy: Source, supply chain and sink. *Renewable & Sustainable Energy Reviews*, 2017, 69: 735-749.