Land Use Policy 49 (2015) 118–130

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Global supply chain of arable land use: Production-based and consumption-based trade imbalance

G.Q. Chen[a,b,*], M.Y. Han[a,b,*]

[a] College of Engineering, Peking University, Beijing 100871, PR China
[b] NAAM Group, Faculty of Science, King Abdulaziz University, Jeddah 21589, Saudi Arabia

ARTICLE INFO

Article history:
Received 13 June 2015
Received in revised form 14 July 2015
Accepted 20 July 2015

Keywords:
Global supply chain
Input-output analysis
Arable land use
Food supply
Trade imbalance

ABSTRACT

Closely related to food supply, arable land use has been extensively studied, especially regarding booming global trade activities. However, the analysis on trade patterns of arable land use, particularly in terms of intermediate use and final demand, is still lacking. To shed light on the complex arable land use relationships among economies, the global supply chain of arable land use is intensively explored in the present work by a systems multi-regional input-output analysis for the year of 2010, with focus on the trade patterns from the perspective of production and consumption. Global arable land use embodied in international trade is estimated near one third the global arable land use, and that embodied in intermediate use is almost twice that embodied in final demand. Arable land use trade patterns are noted in terms of production-based imports/exports and consumption-based imports/exports. Most notably, Mainland China is shown as the leading production-dominated importer. With regard to other large economies, Canada is found as a production-oriented exporter, in contrast to Australia as a consumption-oriented exporter. Japan is identified as a production-oriented importer, while the United States is a consumption-oriented importer. As heavy trade imbalance is revealed prevailing not only between countries and regions but also between intermediate products and final goods, the study to explore global supply chains of arable land use can provide essential policy making implications for security and sustainability in arable land use and food supply on both global and regional scales.

1. Introduction

Food supply is always a global focus. Since a surge in international cereal prices over 2007 and 2008, over 130 million people were affected, and 75 million additional people became malnourished (Headey, 2011). In global food supply chains, a significant role has been played by huge arable land use hidden in booming commodity trade (Qiang et al., 2013; Tilman et al., 2011). A country consumes massive amounts of goods and services from both domestic and global markets, and thus imposes pressure not only on its domestic arable land resources, but also upon other countries and regions' (Verhoeve et al., 2015; Weinzettel et al., 2013). In context of the inter-connected global economy that features an intensive correlated supply chain (Davis and Caldeira, 2010), the analysis on global supply chains of arable land use gains its essential significance (Garrett et al., 2013a,b).

Developed and refined by Leontief (1986), input–output analysis (IOA) method played an important role in guiding macroeconomic policies (Lenzen et al., 2013a; Peters and Hertwich, 2008). By interconnecting resource flows and environmental impacts to categories of both intermediate use and final demand through inter-industrial connections, IOA method is well-established to analyze ecological elements and environmental resources in the globalized economic system (Chen and Chen, 2011a,b). This method presents a swift extension to land use accounting (Hubacek and Sun, 2001; Lenzen et al., 2003; Wood et al., 2006). Subsequently, land use accounting on the global, national, and urban scales have been a recent concern (Guo et al., 2014; Lenzen et al., 2007; Steen-Olsen et al., 2012; Wiedmann et al., 2007). Among them the land use transferring throughout the world has arrested extensive attention, in which the comprehensive analyses on global land displacement and discussions on global land concerns were fully elaborated (Weinzettel et al., 2013; Yu et al., 2013). In addition to the above up–down analyses, physical accounting as a kind of process analysis method made a great contribution to land use

---

* Corresponding authors at: College of Engineering, Peking University, Beijing 100871, PR China. Tel.: +86 10 62767167; Fax: +86 10 62754280.
E-mail addresses: gqchen@pku.edu.cn (G.Q. Chen), myhan@pku.edu.cn (M.Y. Han).

http://dx.doi.org/10.1016/j.landusepol.2015.07.023
0264-8377/

Table 1
Multi-regional input–output table for global economy.

Output / Input		Intermediate use							Final demand		
		Region 1			···	Region m			Region 1	···	Region m
		Sector 1	··	Sector n		Sector 1	···	Sector n			
Region 1	Sector 1	z_{ij}^{rs}							f_{ii}^{rs}		
	···										
	Sector n										
···											
Region m	Sector 1										
	···										
	Sector n										
Resources use		u_i^r									

accounting as well on basis of international and regional food trade data (Gerbens-Leenes et al., 2002; Kastner and Nonhebel, 2010; Kastner et al., 2011, 2012).

Above mentioned studies are considered valuable for land use assessment. However, the analysis on trade patterns of arable land use, particularly in terms of intermediate use and final demand, is still lacking. Compared to trade in final goods and services, trade of intermediates is more sensitive to trade costs and inert to bilateral market size (Miroudot et al., 2009). Besides, trade flows somewhat tend to be dominated by intermediate products instead of final goods (Miroudot et al., 2009). Taking up nearly two thirds the global trade volume, intermediate trade deserves certain attention (Johnson and Noguera, 2011).

At the moment, countries such as the United States, Japan, Russia, and the European Union are facing an economic downturn. For Mainland China, the economy has stepped into the “new normal” age with a growth rate at around 7%. In the same period, some emerging economies are flourishing. Tremendous changes have taken place, and an urgent need is required to explore the global supply chains of arable land use.

In this context, the global supply chain of arable land use is intensively explored in the present work by means of a systems multi-regional input–output analysis. With focus on the trade patterns from the perspective of production and consumption, relationships of arable land use between economies are clearly elaborated with descriptive statistics and systematic analysis. The remainder of the paper is structured as follows: Section 2 articulates the method employed in this study, Section 3 summarizes the detailed results, Section 4 discusses the trade patterns in different economies, and in the final section the concluding remarks are drawn.

2. Method and materials

To quantify and analyze the embodiment of resources and emissions in different economic activities, input–output tables, in particular multi-region input–output tables, are well-employed for exploring economic interdependency of different economies and frequently applied to assess human induced energy and environmental issues, such as energy consumption (Chen and Chen, 2013a), carbon emissions (Chen et al., 2013; Peters and Hertwich, 2008), water use (Chen and Chen, 2013b; Han et al., 2014, 2015; Lenzen et al., 2013a), and land displacement (Weinzettel et al., 2013; Yu et al., 2013). This method integrates ecological endowments and environmental emissions with economic network to reveal the resources and emissions profiles associated with economic flows. Extended from the economic input–output table, the ecological multi-regional input-output table is built profiling both monetary and ecological flows of the target system, with m regions each involving n sectors as presented in Table 1. For the global economy concerned, the systems conservation for resource use of Sector i in Region r requires:

$$u_i^r + \sum_{s=1}^{m}\sum_{j=1}^{n}\epsilon_j^s z_{ji}^{sr} = \epsilon_i^r x_i^r \tag{1}$$

where u_i^r represents direct resources input of Sector i in Region r, ϵ_j^s represents embodied intensity of Sector j in Region s, z_{ji}^{sr} represents output from Sector j in Region s for intermediate input to Sector i in Region r, x_i^r represents gross output of Sector i in Region r given as:

$$x_i^r = \sum_{s=1}^{m}\sum_{j=1}^{n} z_{ij}^{rs} + \sum_{s=1}^{m} f_{ii}^{rs} \tag{2}$$

where f_{ii}^{rs} represents output from Sector i in Region r for final demand of Sector i in Region s.

Subsequently, the conservative matric form can be expressed as:

$$U + EZ = E\hat{X} \tag{3}$$

in which, $U = [u_i^r]_{1\times mn}$, $E = [\epsilon_j^s]_{1\times mn}$, $Z = [z_{ji}^{sr}]_{mn\times mn}$, diagonal matrix $\hat{X} = [x_{ij}^{rs}]_{mn\times mn}$, where $r, s \in (1, 2, \ldots, m)$, $i, j \in (1, 2, \ldots, n)$, $x_{ij}^{rs} = x_i^r$ when $(i = j) \cap (r = s)$ and $x_{ij}^{rs} = 0$ when $(i \neq j) \cup (r \neq s)$, and in which diagonal matrix $\hat{F} = [f_{ij}^{rs}]_{mn\times mn}$, where $r, s \in (1, 2, \ldots, m)$, $i, j \in (1, 2, \ldots, n)$, $f_{ij}^{rs} = f_i^r$ when $(i = j) \cap (r = s)$ and $f_{ij}^{rs} = 0$ when $(i \neq j) \cup (r \neq s)$.

Therefore, with properly given direct inputs matrix U, intermediate inputs matrix Z, and total outputs matrix $\hat{X}$, the embodied intensity matrix can be obtained as:

$$E = U\left(\hat{X} - Z\right)^{-1} \tag{4}$$

In this way, the embodied intensity based on the conservation law is obtained equally applicable to both intermediate use and final demand, to support systems accounting for all the inter-sectoral and inter-regional supply chains. This is different to the case with the conventional environmentally-extended IOA, where direct input of environmental resources for each sector is assigned to the virtual use of environmental resources of final demand by