Physica A 509 (2018) 998–1008

Contents lists available at ScienceDirect

Physica A

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

Competition and transmission evolution of global food trade: A case study of wheat

Chao Dong [a,b], Qiuju Yin [a], Kevin J. Lane [c], Zhijun Yan [a,d,e,*], Tianyu Shi [f], Yan Liu [a], Michelle L. Bell [g]

[a] School of Management and Economics, Beijing Institute of Technology, Beijing, China
[b] State Information Center of National Development and Reform Commission, Beijing, China
[c] Department of Environmental Health, Boston University School of Public Health, Boston, MA, USA
[d] Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing, China
[e] Sustainable Development Research Institute for Economy and Society of Beijing, Beijing, China
[f] School of Economics and Management, Zhejiang Sci-Tech University, Hangzhou, China
[g] School of Forestry and Environmental Studies, Yale University, New Haven, CT, USA

HIGHLIGHTS

- Competitive relationship of global wheat trade is considered in this study.
- A wheat-trading competition network is constructed using complex network.
- A novel indicator "competitive intensity" is introduced in this paper.
- Large wheat importers play important roles for evolution of the competition pattern and transferring wheat-trading competition.

ARTICLE INFO

Article history:
Received 22 November 2017
Received in revised form 17 May 2018
Available online xxxx

Keywords:
Wheat
Competition
Food security
Complex network

ABSTRACT

Food trade plays an important role in improving each country's food security, and will be even more critical under climate change. Previous literature mainly analyzed the evolution of global food trade from the view of importers with less attention to the possible competitive relationships among importers. In this paper, we explored global food trade from the perspective of competition and investigated regions and countries' adaptive behaviors to enhancing food security in relation to weather patterns, which is relevant to climate change. We collected global wheat trade data from the UN Comtrade database and constructed wheat-trading competition networks. We studied overall features, core–periphery structure (differentiating the whole network into two groups: the core and the periphery) and the evolution of the network over time. The results revealed that wheat trade had formed a global competition pattern, while the number and tightness of competitive relationships gradually decreased with time. A second finding was that core countries and periphery countries were clearly identified in the wheat competition network. Large wheat importers such as Italy, Egypt, Japan and Algeria, were the main driving force for evolution of the competition pattern and played important roles in transferring wheat-trading competition. Finally, a targeted policy framework was put forward to promote the stability and healthy wheat-trading environment.

* Correspondence to: School of Management & Economics, Beijing Institute of Technology, Beijing 100081, China.
E-mail address: yanzhijun@bit.edu.cn (Z. Yan).

https://doi.org/10.1016/j.physa.2018.06.052
0378-4371/

1. Introduction

With economic development in agricultural technology, the past half-century has seen marked growth in food production, allowing for a dramatic decrease in the proportion of the world's people that are hungry, despite a doubling of the total population [1]. However, climate change can strongly impact food production [2–4], influencing global food security [5,6]. Today 795 million people still do not have access to sufficient protein and energy from their diet, and even more suffer from some form of malnourishment [7]. Meanwhile, most food consumed worldwide is grown locally. Where there is not enough local production to meet demand, trade has been instrumental in filling the gap and further plays an important role to enhance each country's food security [8].

In recent decades, a number of researchers have examined whether food trade influence food security. Dorosh [9] analyzed how rice trade liberalization between Bangladesh and India affected national food security, with results indicating that trade liberalization offered potential benefits for food security by enabling a rapid increase of food supply. Tanaka [10] used a Computable General Equilibrium (CGE) model with a Monte Carlo simulation to quantify the impacts of rice trade on national food security and found little evidence of Japan suffering from trade shocks. Asche [11] studied the relationship between food security and the global trade of fish and seafood between developing and developed countries. The results showed that developing countries exporting high-quality seafood in exchange for lower quality seafood would not have bad effects on food security. Meanwhile, other researchers considered complex trade relationships as a whole system and applied complex network theory, which is widely applied in different fields [12–17], to analyze the global trade relationships of food and their derivatives (like "virtual water", that is water resources used to produce food commodities) [18–23].

Owing to the different natural conditions and agricultural technology, grain production varies dramatically among countries. Take wheat as an example, a small group of countries, such as the US and Canada, contribute most of world's wheat production, which leads to several countries importing wheat from the same exporter and forces them to compete with each other. Previous researches using complex network theory mainly analyzed the evolution of food trade. In this paper, we attempt to analyze such competition from the importers' perspectives (demand side). In addition, previous literatures adopting complex network theory mainly focused on the networks' structural characteristics, while only a few works [22–25] studied trade policy of food security based on these analysis. In global food trade system, identifying dynamic competitive relationships and studying the path of its evolution are of great importance for food importers to master new rules of global food trade and develop import strategies that not only enhance competitiveness but also create healthy competition within global food trade and ensure global food security, especially under climate change.

This paper focuses on wheat, the largest trade volume of crops and an important commonly imported food [8,26]. Besides, the studies of global wheat trade and production have attracted much scholars' attention for decades [27–30]. Therefore, we constructed global competitive wheat networks and studied the overall features, core–periphery structure (differentiating the whole network into two groups: the core and the periphery) and the evolution of network over time. Meanwhile, we address the following questions: What are the main features of global competition network for wheat? Which regions play significant roles and dominate the wheat competition network? Which competitive intensities among countries are strong and which countries face severe wheat insecurity?

This study contributes to the literature in three aspects. First, we apply complex network theory to analyze the overall features and evolutionary patterns of the wheat trade network from a competition perspective, which has received little attention in the existing literature. Second, considering the difference of network links, a new indicator, i.e. competitive intensity, is introduced in the wheat-trading competition network. The competition is divided into two types: direct competition and indirect competition. Third, a targeted policy framework is proposed to promote the stability and healthy evolution of wheat-trading competition.

The rest of the paper is organized as follows. Section 2 defines the trade network and proposes the indicators for network analysis. Then, the empirical analysis and results of wheat trade network are discussed in Section 3. We conclude with some policy suggestions and future research directions in Section 4.

2. Models and methods

2.1. Competition network modeling

We take global wheat-trading competition as a network and apply the set $G = (V, E)$ to describe, where wheat importers $V = (v_1, v_2, \ldots, v_n)$ are represented as competition network nodes, and competitive relationships $E = \{e_{ij}\}$ are denoted as network links, where a link represents the competitive relationship between countries. If countries v_i and v_j import wheat from the same country, $e_{ij} = 1$, otherwise, $e_{ij} = 0$. We only consider competitive relationships and construct a wheat-trading competition network based on whether wheat importers have the same exporter to study the structural evolution of the wheat-trading competition pattern. Besides, due to the differences in import sources and import volume, the levels of competitiveness may be different for different competitive relationships. Thus, we further take indicator "competitive intensity" as the links' weights (a large value of weight means high level of competitiveness) and construct a wheat-trading weighted competition network. Moreover, the evolution of the global wheat-trading competition is explored based on the weighted competition network.