Energy 102 (2016) 406–415

Contents lists available at ScienceDirect

Energy

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

Estimating potential trade links in the international crude oil trade: A link prediction approach

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ARTICLE INFO

Article history:
Received 22 May 2015
Received in revised form
14 October 2015
Accepted 16 February 2016
Available online xxx

Keywords:
Trade links
Crude oil
International trade
Link prediction

ABSTRACT

Estimating potential trade links is essential for exploring the information implied by international crude oil trade data, which contain obvious trade links among countries. In addition, it is important for governments to assess the evolution trend of international crude oil trade in order to avoid trade risk. This study introduces the link prediction approach to explore potential trade links from the perspective of relations based on the topological attributes of countries. We take the number of common trade partners for each country pair as the potential linking motivation. Based on this, we confirm this as a general feature for most existing trade links and thereby describe the real distribution of trade relations. Furthermore, our study analyzes the practical meanings of explored potential trade links with considerations of countries' crude oil trade roles. We find that the number of common trade partners is indeed one of the structural linking motivations in international crude oil trade. It can not only represent the possibility of trading relations, but also reflect the competition among countries. By using this evaluation index, we then estimate potential trade partners combined with countries' crude oil trade roles and provide suggestions for governments about future trading strategies.

1. Introduction

It is clear that oil-rich countries trade with countries that have poor oil reserves, while countries with a lack of oil expand their crude oil trade relationships with both oil-rich and oil-poor countries in order to satisfy their oil requirements and safeguard their energy security. However, *potential* trade links also exist among countries. Indeed, estimating these potential trade links is essential for researchers to explore crude oil trade relations among countries [1,2] that are not explained by the available data [3,4]. Although countries may not obviously trade, the trade patterns and interactions between each pair of countries form links, which may encourage them to trade in the future. Thus, estimating potential trade links allows researchers to evaluate implied trade links, which can easily be neglected. Further, this endeavor is meaningful for governments because they are eager to increase their understanding of international crude oil trade in order to avoid trade risk [5]. Based on the foregoing, this study explores potential trade links from a fresh perspective based on international crude oil trade patterns.

Most previous studies focus on analyzing the structure and evolution of international crude oil trade patterns [6]. Some expand their descriptions of trade relations to include competition [4,7], while others examine the reactions of countries when facing crises or global events [8]. In addition, some authors have attempted to predict trade flows for known trade links by using country-level variables such as the gross domestic product (GDP) or currency union [1,9], which cannot be derived from trade patterns. These studies hence focus on the exploration or assessment of obvious, but not potential, trade links. However, the expansion of trade networks has continued to influence international trade relationships and even promote the construction of new trade links.

To estimate potential trade links, we use the link prediction approach [10], which is based on the complex network theory [11], to provide a new insight into these global trade relationships [12,13]. Prior studies about link prediction are mainly about conducting or improving physical models [16–19]. For example, these models have been applied to social networks which aim to make

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http://dx.doi.org/10.1016/j.energy.2016.02.099
0360-5442/

better friendship recommendations [20], biological networks which aim to explore unknown neural interactions [21], and US air transportation networks which aim to estimate the possible construction of airlines [10]. These networks have thus been used to measure algorithm precision [22], which confirms that it is useful for estimating potential network links. Thus, we apply link prediction to estimate potential trade links in international crude oil trade. Analyzing the observed network structures and statistical properties of selected countries allows us to investigate the potential motivation behind the construction of existing trade links [14,15].

In this study, we estimate potential trade links based on real trade patterns in order to provide a fresh perspective on trade relations among countries. In order to describe the linking motivation of international crude oil trade, we define an evaluation index calculated by using the topological attributes of the observed countries. We then use a test index to examine the ability of our evaluation index to estimate the distribution of real trade links. Furthermore, our research compares the potential trade links proposed by our estimation results based on the tested evaluation index with real trade links to assess the evolution of these potential ones. Then, to explore the practical meanings of potential trade links which provide more clear and instructive information, we divide involved countries into different crude oil trade roles which synthetically consider the crude oil importation, exportation and proved reserves respectively. Through the division of comparisons and countries' crude oil trade roles, we finally obtain further practical understanding of these trade links. From the perspective of the consideration of the topological attributes of each pair of countries, our work not only estimates relationships that have potential trade links formed by real trade patterns, but may also allow us to predict future new trade cooperation or competition between certain pairs of countries.

The remainder of this paper is organized as follows. The next section introduces the data source and algorithm steps of link prediction. Section 3 confirms the feasibility of the proposed evaluation index and analyzes the empirical results. Section 4 discusses, including making estimations about future trade relations. Section 5 concludes.

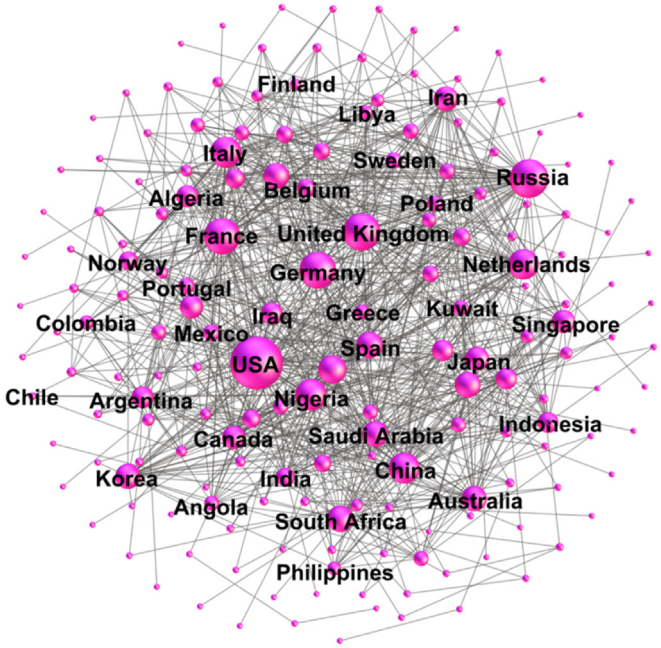

Fig. 1. Countries and their relations in international crude oil trade in 2000.

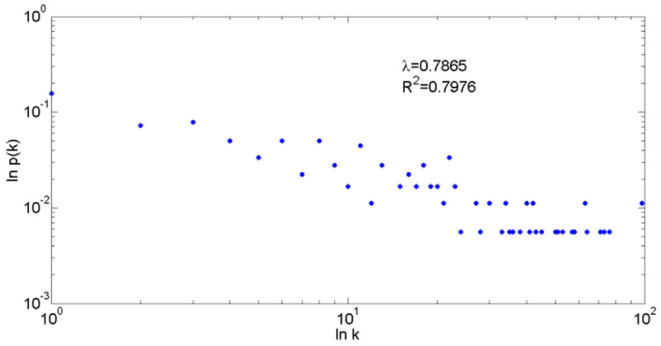

Fig. 2. The power-low distribution of international crude oil trade in 2013.

2. Data and methodology

2.1. Data

This study derived data on international crude oil trade (HS Code 270900) from UN Comtrade, annually from 2000 to 2013. We cleaned repeated data and labeled existing trade relationships for each pair of directly related countries in each year, without any consideration of trade flow and volume. Existing trade relations are defined as those with a clear record of trade value or weight. We used the trade relationships among countries in 1 year as the data-processing unit. As a result, we obtained 13 data units. Fig. 1 shows the pairs of countries and their existing trade relations in the international crude oil trade in 2000.

Taking the 2013 data unit as an example (Fig. 2), international crude oil trade is a typical network with the characteristic of power-low distribution, $p(k) \sim k^{-\lambda}$, where k is the amount of direct trade partners for each country; p(k) is the frequency of each k; R^2 is the goodness-of-fit; λ is the degree of power-low distribution, which means that smaller countries hold the bulk of oil resources.

2.2. Methodology

2.2.1. Link prediction model

Based on the structural properties of each pair of countries, we applied the link prediction approach to the annual data on international crude oil trade. The link prediction algorithm presented in this subsection has been described in detail by previous link prediction papers [10,12,13]. We herein only show the steps briefly combined with the characteristics of international crude oil trade. The variables used to deal with each data unit are shown in Table 1.

Given the status of international crude oil trade, we show the algorithm in the following five steps:

(1) Define an evaluation index based on the structural properties of countries

We use common neighbor (CN) as the evaluation index. Under the CN approach, the higher the score of a link, the higher is its construction possibility. CN is generally considered to be the most effective index for evaluating the linking probability for most types of research objects [10,13]. In particular, for those networks apparently characterized by a power-low distribution such as international crude oil trade networks, CN always has better performance than most other complicated evaluation indexes. Thus, it is reliable to use this index to describe the construction of trade links.