The economic interdependence of industries: a network science approach

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Objective

This study focuses on the interdependence of different industries and wishes to examine how sectors support each other in growth. It contributes to the research into economic inter-industry relations by suggesting a new approach to analyse input-output models from a network science perspective.

No industry can exist and develop individually. All sectors are interdependent through the exchange of products and services. [1] Our research argues that we must analyse detail-level input-output models with a high number of sub-sectors to understand the most accurate structure of the network of industries. We develop and explore the detail-level network of 405 sectors by concluding where the industry inter-dependence network goes through a 'scale-free – random' topology shift. Besides this, the study answers the question of whether there are any 'super industries' in our society that are required everywhere and how many resources they pump into the cycle of industry development. The research is also interested in the bigger picture: whether the field of sectors is symmetric, and do the industries need the same amount of resources as they give as support?

Background

Given the increasing complexity of our society, we cannot examine a problem without the help of interdisciplinary approaches. Inter-industry relations are profoundly interdisciplinary; therefore, we must use techniques that view industries from a systematic perspective and understand the complexity of relations. In this study, we use network science tools to explore industry interrelatedness through the help of input-output analysis. Leontief's [2, 3] economic input-output models represent, in mathematical form, the monetary transactions between industry sectors. They specify what goods and services (output) are consumed by other industries (input).

The network science approach of input-output models is not a novel concept. There are mainly two basic approaches currently being adopted in this research area. One is the analysis from a supply chain perspective, using company-level data [4, 5, 6], and the other is the industry perspective.

In the industry perspective approach, a considerable amount of literature has been published using the World Input-Output Database [1, 7, 8, 9], covering 40 countries in the 2013 release and 43 countries in the 2016 release, all with 35 (2013) and 56 (2016) sectors. [10] In recent years, researchers have also investigated various approaches to the input-output transaction data of the US economy as systematised by the Bureau of Economic Analysis (BEA). [11] Most of the studies focused on the sector and summary level of the input-output accounts containing 21 (sector-level) and 71 (summary-level) aggregated industries. [12, 13]

Methodology & Results

Although extensive research has been carried out from an industry perspective, just a few studies exist which develop a network of at least 400 detail-level industries. This can be a key problem because the networks built on a highly aggregated level with few nodes and connections don't represent the industry interdependencies accurately. On the one hand, the topology of a detail-level industry network can differ considerably from an aggregate-level network. The first one tends to be way denser with more less-weighted connections, thereby behaving differently. On the other hand, some essential links could be hidden in an aggregated-level network. For example, embedded in a highly-weighted connection, several detail-level links could have been hidden that might be more important than the other present aggregated ones. The whole map of industrial interdependence could change when analysing these separately. The detail-level input-output account data could allow us to discover a more representative picture not with just more separable sectors, but with way more supporting connections between industries, in number and in validity too. Therefore, we use the US BEA detail-level database [11], broken down into 405 sub-sectors, to carry out this research.

We used the last release, the 2012 total requirements table - industry by industry, including 405 industries and their inter-industry purchases. The network built from this database is a directed weighted graph. The vertices are the industries, the directed connections are the monetary transactions, and the weight of each link is the economic value, representing how much an industry supports the development of the other. It is the input by the industry required (directly and indirectly) from the source industry in order to deliver one dollar of output to final users.

While Carvalho (2010, 2014) used a network perspective on the detail-level data from 1997 [14] and 2002 [15], he disregarded the weights of connections and defined the threshold for cutting the edges at 1% of an industry's total input purchases. He argues that the analysis still accounted for about 80% of the total value of input trade; however, with this threshold, the study fails to consider 90% of the initial connections, focusing on a very sparse network.

By contrast, we define several thresholds in this research and examine network topology and measures at different levels. Grazzini and Spelta [8] showed that in the 35-industry world input-output network, both out-strength and in-strength flows have heavy tail distribution in their network. We also compare in-degree and out-degree distribution in the 405-industry network by concluding at which threshold the network behaves like a random or scale-free graph. We do this by calculating statistical measures when comparing the network's degree distribution to the degree distribution of a random and scale-free graph developed with the same properties as the original network. The results show that the in-degree and out-degree distributions of the industry network behave very differently, and we examine what that means for the industrial landscape.

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