Physica A 392 (2013) 1202–1214

Contents lists available at SciVerse ScienceDirect

Physica A

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

Network analysis to detect common strategies in Italian foreign direct investment

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ARTICLE INFO

Article history:
Received 13 December 2010
Received in revised form 19 June 2012
Available online 7 November 2012

Keywords:
FDI
Economic networks
Projected network

ABSTRACT

In this paper we reconstruct and discuss the network of Italian firms investing abroad, exploiting information from complex network analysis. This method, detecting the key nodes of the system (both in terms of firms and countries of destination), allows us to single out the linkages among firms without ex-ante priors. Moreover, through the examination of affiliates' economic activity, it allows us to highlight different internationalization strategies of "leaders" in different manufacturing sectors.

1. Introduction

Recent trade literature has highlighted highly heterogeneous behavior of individual firms [1,2]. To tackle the challenges of globalization, some firms have upgraded quality, others lowered costs: employing migrants, outsourcing or off-shoring; others have merged with foreign firms and/or established subsidiaries abroad. In this paper, exploiting network analysis, we reconstruct and discuss the *network* of Italian firms investing abroad with the aim of highlighting possible different strategies at sector level and/or the presence of common patterns.

In the last decade, complex networks analysis has received a great deal of attention in both natural and social sciences [3] as a complement of standard analyses, since it allows an alternative reconstruction of the links and the evolution of the connections between different individuals/agents/firms. It has at first been widely used to understand the basic mechanisms of the Internet, and World Wide Web [4], and e-mail networks [5]. Each of these systems is formed by agents that interact and compete receiving reciprocal advantages. The interactions are quantitatively analyzed by means of topological indexes. To exploit the potentiality of network theory has allowed substantial improvements in the understanding of the underlying mechanisms.

We believe that this approach should also be common in economics, since it can improve the understanding of economic systems where firms, households, individuals and the State interact. It can also help explaining stylized facts, with simple models related to stationary and non-stationary contexts. Pioneering empirical works in economics deal with the financial markets structure [6], the European firms' network [7], the relationship between firms and banks [8–10]; the literature is rapidly increasing also for flows of international trade [11,12], and migrants and FDI. To the best of our knowledge, this study is the first application of graph and network theory to Italian Foreign Direct Investment (FDI). It aims at understanding: (i) whether the internationalization modes depend on proximity (at sector and geographical level); (ii) what are the main hubs (countries/firms) within the sectors; (iii) what are the strategies employed by the main actors (firms); (iv) whether the main actors are the largest firms.

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0378-4371/$ – see front matter
doi:10.1016/j.physa.2012.10.033

In what follows, we start by explaining the methodology used (Section 2). We then sketch the literature on heterogeneous firms and internationalization modes (focus on FDI) and explain what network theory can add to existing models and empirical analyses (Section 3). Section 4 presents the general results comparing them with the implications of the theoretical models. It also presents a focus on three sectors particularly relevant for the Italian economy; Section 5 concludes.

2. Network: the method

Network analysis allows us to investigate the topological properties of the complex structure of economic relationships. From a mathematical point of view, a network is represented by an adjacency matrix. The element of the adjacency matrix a_{ij} indicates that a link exists between nodes i and j; that is $a_{ij} = 1$ if investor i goes to country j; otherwise $a_{ij} = 0$.

The *degree* of a node i is the number of its links and is calculated by:

$$k_i = \sum_j a_{ij}. \tag{1}$$

This is a measure of node importance and centrality. The *distance* d_{ij} between two vertices i, j is *the shortest* number of edges to go from i to j. Therefore, the neighbors of a vertex i are all the vertices j which are connected to that vertex by a single edge ($\mathrm{d}_{ij} = 1$). Using the adjacency matrix this can be written as:

$$\mathrm{d}_{ij} = min\left\{\sum_{k,l\in\mathcal{P}_{ij}} a_{kl}\right\} \tag{2}$$

where $\mathcal{P}_{ij}$ is a path connecting vertex i and vertex j.

The *diameter* of a graph is given by the maximum of all distances between pairs. Many definitions of 'centrality' have been given in network analysis. A first measure of centrality is degree centrality, defined as:

$$\mathrm{d}c_i = k_i/(N-1). \tag{3}$$

The second definition is based on dynamical properties of the graph and is given by the number of times that one vertex k is crossed by a minimal path from one vertex i to j (also called distance d_{ij}). This quantity is called *site betweenness* b_i and is usually defined by:

$$b_i = \sum_{\substack{j,l=1,N \\ i\neq j\neq l}} \frac{\mathrm{d}_{jl}(i)}{\mathrm{d}_{jl}} \tag{4}$$

where d_{jl} is the total number of different shortest paths (distances) going from j to l and $\mathrm{d}_{jl}(i)$ is the subset of those distances passing through i. The sum runs over all pairs with $i \neq j \neq l$.

Another measure of centrality is the *closeness centrality*:

$$cl_i = \frac{N-1}{\sum_j \mathrm{d}_{ij}} = \frac{1}{\bar{d}_i} \tag{5}$$

which is the reciprocal of the average distance from that node to the other nodes (see Refs. [13–15]).

The visualization of a graph is a crucial point in the study of a network. The study of automatic drawing is a very active field of research. The aim is to obtain a way to represent in the Euclidean space an object (the graph) which is defined only on the topological space. Many algorithms have been proposed. Among them, the Kamada–Kaway algorithm [16] is based on the idea that the suitable geometric distance between two vertices in the drawing represents the topological distance between them in the graph. The network is represented like a set of particles (nodes) connected by springs. The final network visualization is based on the minimization of the energy associated to this set of coupled harmonic oscillators. This approach allows us to represent nodes close to each other, pertaining to the same group (connected by many links).

In the empirical exercise for this paper, a link is drawn if a firm invests in a specific host country. The main statistical indicators are: degree distribution of each of the two kinds of nodes, scaling of clustering coefficient with respect to the degree, correlations among the degree of the two kinds of nodes. As explained below, we extract from the overall network, two networks, each one composed by just one kind of nodes. These two networks are called projected networks, in the sense that they are obtained as a projection of the initial graph in the subspace composed by nodes only of the same kind (see 2.1).

2.1. Projected network

In the study of bipartite graph, a widely used approach is to study separately two networks defined from the original network. Let us refer to nodes A and B; we can study the network G_{A+B}, which has the total set of nodes ($A + B$), or the networks G_A and G_B, which have only nodes of kind A or B respectively [17–19]. The bipartite network of countries and firms is plotted in Fig. 1, top panel, while the network projected into the subspace of corresponding firms is plotted in Fig. 1, bottom