A Network Analysis of Foreign Direct Investments

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Abstract

The fragmentation of production is a major feature of modern economies and it is completely changing how multinationals produce. We reconstruct and discuss the network of European (EU28) investing abroad firms, exploiting information from complex network analysis. The study is based on the fDi Markets database provided by the Financial Times, reporting global greenfield foreign direct investments. Keeping in due consideration both sectors and countries of destination, and without ex-ante prior, we single out the linkages among investors. We focus on three relevant sectors (Textile, Machinery and Coal), highlighting the evolution of network's structure. In order to do this, we use network indexes and we examine the internationalization activities both in terms of country of destination and characteristics of the main leaders.

Key words: Foreign Direct Investment, Economic networks, Projected network

JEL codes: F23, D85

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1 Introduction

The fragmentation of production is a major feature of modern economies. This process has a strong and visible impact on economic agents and on firms' strategies as they have to deal with a more competitive environment. The firms' ability to survive in the new context created by the fragmentation of production depends upon their capacity to innovate their products and processes as well as on their ability to penetrate new markets. The impressive growth in the number of firms involved in exports, FDI and global outsourcing reveals that firms reply to globalization by developing internationally oriented strategies. Business relations were the prevailing form of internationalization until some years ago, on the contrary nowadays firms use more complex modes to become international. Major international integration has been associated with strong manufacturing reorganization both inside and outside the country. The uncertainties surrounding the developments of internationalization have made politicians, businessmen and ordinary citizens of every nation aware of the need to constantly monitor the evolution of international markets. This way agents can promptly analyse the changes and limit the possible adverse effects on the economic system, particularly in terms of employment. At the same time, being aware of the new spatial distribution of firms, due to the fragmentation of production, policy makers could better understand the long-run economic trends. Finally, a deeper comprehension of heterogeneity, clearly pervasive in the economic system, could be fair of insights on the economy development.

In his seminal paper, Melitz (2003) links the role of heterogeneity with the decision to export, highlighting that only the more productive firms are able to bear the cost of exporting and therefore to access international markets. Less productive firms are confined to domestic markets, or they have even to exit the market. In a similar way, but accounting for more complex modes of internationalization, Helpman et al. (2004) generalize these results, incorporating horizontal Foreign Direct Investment (FDI). The underlying idea is that there are relatively few firms able to compete in international markets and these firms are more productive, pay higher wages, employ more skilled workers and invest more in R&D. Theoretical works have therefore highlighted a clear-cut ranking in the productivity of firms such that the most productive firms will invest abroad, the second most productive will serve foreign markets through exports, and the least productive will 'stay domestic'. Empirical studies, based on this approach, have also shown heterogeneity among firm size, wages paid, as well as strategies adopted to penetrate foreign markets. However, the clear-cut ranking is valid only on average. The empirical distribution of productivity, net worth or size among firms adopting different internationalization modes have some area of overlapping. For example while, on average, exporters are more productive, there are domestic firms with productivity higher or equal to exporters. This overlapping can be easily explain by the coexistence of different sources of heterogeneity which may af-

fect in the chosen modes of internationalization. Indeed, the international literature has already moved far beyond, introducing other sources of heterogeneity such as innovation activity (Bustos, 2011), product quality (Hallak and Sivadasan, 2013, Manova and Zhang, 2012, Crino' and Epifani, 2012), demand factors and uncertainty (Albornoz, et al 2012, Di Comite et al. 2014) and financial fragility (Chaney, 2005; Manova 2013; Assenza et al., 2016).

The distributions of the variables of interest are also strongly disperse, detecting that heterogeneity is pervasive not only between but also within groups. Giovannetti et al. (2016), through econometric analysis on Italian data, shed light on the sources of heterogeneity in productivity among foreign direct investors; in particular, they investigate the links between parent productivity and affiliates characteristics such as their number, location, turnover and sectoral characteristics. They try to explain the heterogeneity (in terms of productivity) within foreign direct investors, looking at the strategies firms adopt: how far they go, what features the countries of destination have, if they prefer greenfield investments to M&A and so on. In the same line, but in a complementary way, De Masi et al. (2013) build and study the network of Italian firms that invest abroad, highlighting the linkages among firms and identifying the key nodes of the system (both in terms of firms and countries of destination). They show that even foreign direct investors that operate within the **same sector** can adopt different internationalization strategies: some firms invest abroad (horizontal FDI) using middle-large countries as a productive platform to export in neighboring through commercial affiliates; other firms are global players (vertical FDI), and their production is carried out for cost-saving reasons, and/or in search of professional skills; finally, most foreign activities seem to be linked to commercial purposes, in the attempt to promote exports. Thus, by means of network analysis they introduce an additional aspect in the debate : heterogeneity is also strong within the same sector.

The present analysis is in line with applications of complex network theory to Economical systems (Schweitzer et al., 2009). In the last decade, complex networks have been set up as a cross-cutting research field in various disciplines of natural sciences (physics and biology) and social sciences (Dorogovtsev, Mendez 2003). Networks make it possible to reconstruct the connections and the evolutions of connections that occur between different individuals / agents / businesses. In particular, several studies have been carried out to understand the mechanisms underlying communication networks: Internet, World Wide Web (WWW) and e-mail networks (Vega-Redondo, 2007). These communication networks are a mirror of the underlying social network, composed of a group of agents who collaborate and compete with each other, gaining mutual benefits from interaction. This approach is promising for the study of economic systems, in which businesses, families, individuals and the State actively interact and shape seamless socio-economic struc-

tures. The study of networks is able to reproduce with simple, stylized and meaningful models both stationary and growth contexts, the latter were so far addressed with game theory and only recently, thanks to better computer tools, with the theory of networks whose mathematical formulation is based on the well-established theory of graphs. The complex network theory, which has only recently been applied to Economics, allow an identification and evaluation of the structures underlying the relationships between different economic units. By way of example, the foreign trade series for Latin American and South-East Asian countries follow the same pattern; however, the network analysis is able to show how the degree of centralization decreased rapidly in Latin America, whereas it grew in South-East Asia. This implied a change in the structure of international trade in the two regions (see Reyes et al., 2008). In the empirical literature the network analysis is mostly used to study the structure of the interbank market (Iori et al., 2008), bank-firm credit market (De Masi et al., 2011; Battiston et al. 2007), financial market investments (Garlaschelli et al., 2005), the world trade network (De Benedictis and Tajoli, 2011), and the world trade web (Fagiolo et al., 2011). Finally, few studies can be found in the literature on FDI at global level. Wall et al. (2011) analyze the network of the top 100 global multinational and ownership linkages in more than 2000 cities worldwide, distinguishing between all industrial sectors and producer service sector. More recently, Alfaro and Chen (2014) analyze a worldwide establishment based database of multinationals using measurements of network density to study agglomeration phenomena. Finally, relatively to European countries, network based analyses have been done on Italian foreign investment data (the above cited De Masi et al., 2013) and on French data (Joyez, 2017).

Within this strand of literature and in line with De Masi et al. (2013), in this paper we reconstruct the *network* of the European (EU28) firms investing abroad. Our analysis makes use of the database **'fDi markets'**: a really rich global detailed database developed by the Financial Times, through which we analyse the relevance of heterogeneity on the network of worldwide foreign direct investments. fDi markets is the main online global database of FDI information; it allows for real-time monitoring of investment projects to track, and profile companies investing overseas. Since 2003, the database has recorded globally over 10 trillion of dollars invested from over 80,000 companies. It is worth noting that only greenfield FDI are recorded and in what follows we will refer interchangeably to affiliates and projects, the name used in fDi markets. We study - separately - the years 2003 and 2015, in order to compare the structural change on the longest available period, and we try to identify changes before and after the crises. In a future work, we will study the entire period, analysing the evolution of the network year by year. In order to create the network, a bipartite graph has been generated, where the nodes are both investors and host countries, and a link is drawn if a parent company invests in a certain host country. Our main aim is to use the network to reveal the existence of heterogeneity between and within sectors and/or the possible presence of common behaviours between firms. To pursue this

aim, we detect the presence of subnets and main hubs (countries/firms) also within specific sectors. Finally, we qualitatively analyse the main actors to discover whether the choice to develop new projects is correlated to specific features of these actors.

In section 2, we present the methodology applied here; then, after presenting the dataset (section 3), first we discuss the main features of the whole sample (section 4), and then of three relevant sectors: Textile, Machinery and Coal (section 5).

2 Network: the Method

Network analysis investigates the topological properties of the complex structure of economic relationships. In order to help the readers, we briefly report the main elements of the network theory used in throughout the chapter. Networks are represented as graphs, that is a set of nodes and links. 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.

2.1 Bipartite network

In the empirical exercise for this paper, a bipartite network is defined (see De Masi, 2008). A network is called bipartite when two kinds of nodes are present, in our case firms and countries. From a mathematical perspective, distinguishing two kinds of nodes C (countries) and I (investors), the graph G_{C+I}, with a total set of nodes $(C + I)$ is defined. A link is drawn if a firm invests in a specific host country, therefore $a_{ij} = 1$ if investor i goes to country j; otherwise $a_{ij} = 0$. A simplified example of a bipartite network of countries and firms is plotted in Fig. 1, top panel.

2.2 Projected network

In the study of bipartite graph, a widely used approach is to study separately two networks defined from the original one. In particular, we extract from the overall graph two graphs, each one composed by just one kind of nodes (countries or investors in our case). These two networks are called projected networks, as they are obtained as a projection of the initial graph in the subspace composed by nodes of the same kind. The two new projected networks are defined G_C and G_I, and they are made up by only nodes of the C or I kind respectively (Peltomaki and Alava, 2006; Sneppen et al., 2004; Guillaume and Latapy, 2004). For the purpose of this paper, I is the network of investors (parent firms investing in the same countries) and C the network of countries (where the firms invest). In Fig. 1, starting from the bipartite network in the top panel, the network projected into the subspace of firms is plotted in the bottom panel.

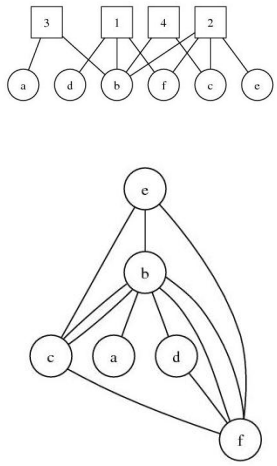


Figure 1: Top panel: bipartite graph, considering the set of investors (circles) $I = 1, 2, 3, 4$ and countries $C = a, b, c, d, e, f$ (squares). Bottom panel: corresponding projected graph on firm's space.

Firms could have a link regardless the number of countries they have in common. However, to retain this kind of information, we define a weighted network[1]: the weight of the link between two firms represent the number of countries they are both connected to in the bipartite network. This leads to the definition of a weighted adjacency matrix W in the firm subspace: the weight associated to the link between two firms is the number of common countries they choose[2]. Therefore, starting from the adjacency matrix of investor-country relationships a_{ic}, the general element of the matrix W is given by

$$w_{ii'} = \sum_{c,c'} a_{ic} \cdot a_{i'c'} \cdot \delta_{cc'}. \tag{1}$$

where δ is Kronecker-delta function: its value is 1 if $c = c'$, otherwise 0. The meaning of the above equation is that two investors i and i' are linked if they invest at least in one common country. The number of common countries they both invest is the weight $w_{ii'}$ of the link between the two investors.

[1]for the sake of graphs' clearness, we do not show the weights in the plots below: there is high level of heterogeneity, very fat and thin links coexist. Therefore, we only discuss weights from a statistical point of view.

[2]We do not use the value of investments as weight because it is really disperse; moreover, for many projects this values is only estimated by fDi markets.

2.3 Network visualization

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-Kawai algorithm (Kamada and Kawai, 1989) 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 to represent close to each other nodes pertaining to the same group (connected by many links).
The visualization process is certainly a first hint to identify common strategies (if any) between different investors. The Kamada-Kawai layout algorithm indeed allows to disclose the presence of highly clusterized nodes and lowly clusterized or even isolated nodes. High clustering shows common strategies between those nodes (investors), meaning that they tend to invest in the same countries. On the other hand, low clustering and isolation of a particular node is an indicator of a singular strategy of that node, different from those of other nodes.

2.4 Topological measurements

Topological measurements allow to understand the roles of different nodes in the network of firms (or countries). The nodes with more connections are called **hubs** of the network. From an economic perspective, we could assume that the hub is a network leader: highly interconnected, with many links and high level of centrality (see below). In the network of firms for instance, a highly connected hub is also usually a very central firm which has a diversified strategy and shares different strategies with many firms. These firms are a driver of the network and their behaviour may affect the one of small players. In this sense, a hub can be considered an economic leader. At the same time, the less connected nodes can be considered the followers in investing activities.

We now turn to the description of relevant measures considered in this work. The basic measure is the **degree** of a node i, which is given by the number of its links and defines its relevance:

$$k_i = \sum_j a_{ij}. \tag{2}$$

The **strength** of a node is defined instead as the sum of the weights of its links.

$$s_i = \sum_j w_{ij}. \tag{3}$$

For our purposes, this measure gives us an insight of projects carried out, but above all of their spatial dispersion. Moreover, to identify the hubs, many definitions of 'centrality' have been proposed in network analysis. We will consider three of them. A first measure of centrality of a node is the **degree centrality**, achieved dividing the degree by the number of nodes of the network:

$$dc_i = k_i/(N-1); \tag{4}$$

where N is the total number of nodes. This measure it will be used here to detect the hubs of subnet (i.e. the sector in this paper).
A second definition, the **betweenness centrality** (Brandes, 2001), is based on dynamical properties of the graph and is given by the number of times that one vertex k is crossed by minimal path from one vertex i to j. Let's define d_{ij}, the **distance** between two vertices i, j, as *the shortest* number of edges to go from i to j, that is:

$$d_{ij} = min\{\sum_{k,l \in \mathcal{P}_{ij}} a_{kl}\} \tag{5}$$

where $\mathcal{P}_{ij}$ is a path connecting vertex i and vertex j. Therefore, the **betweenness centrality** b_i is defined :

$$b_i = \sum_{\substack{j,l=1,N \\ i \neq j \neq l}} \frac{d_{jl}(i)}{d_{jl}} \tag{6}$$

where d_{jl} is the total number of different shortest paths (distances) going from j to l and $d_{jl}(i)$ is the subset of those distances passing through i. The sum runs over all pairs with $i \neq j \neq l$. Let's assume that, in order to minimize the distance, other firms should necessarily pass through a specific node (a firm). In the network builds in this paper, it means that the latter invests in many countries, sharing its own strategy with many other firms. It has an high betweenness and it is an hub. The last measure of centrality employed is the **closeness centrality** (see Freeman, 1977 and Sabidussi, 1966):

$$cl_i = \frac{N-1}{\sum_j d_{ij}} = \frac{1}{\bar{d}_i} \tag{7}$$

which is the reciprocal of the average distance of one node from the other nodes. In order to be an hub, a firm should not be very far from all the others.

3 The Dataset

The dataset is drawn from fDi Markets-Financial times business, which is a global database of greenfield foreign direct investment (FDI) information. Since 2003, it allows real-time

monitoring of fdi projects, classified by business function, across all sectors. It has globally tracked over 10 trillions of investments from over $80,000$ companies. It also includes capital investments and job creation, by tracking and profiling companies investing overseas. To enrich the database, the Financial Times uses different sources: media, project data from industry organizations, information from investment agencies, and data captured from official publications of the companies. In order to validate the data recorded, each project is cross-referenced through multiple sources. Different scholars have already employed data on FDi markets but to our knowledge none of them have reconstructed a network of European FDI. Among the others, Crescenzi et al. (2014) studying EU25, seek to identify the determinants of localization of direct investment separating the role of states from that of regions. Crescenzi et al. (2016) use FDi markets to analyse expansion / localization strategies of EU25 of multinationals in emerging countries; then they compare these strategies with those adopted by multinationals in advanced countries.

For the purpose of this paper, our database comprises outward FDI from each of EU28 (countries of origin) to the rest of the world. Therefore, the countries of destination may be also within the EU28 itself. We employ only data for 2003 and 2015 in order to compare the possible change of the FDI-network, due to the crises. Finally, it is worth noting that differently from De Masi et al. (2013), we do not consider the stock of FDI but the flow (the projects).

4 The Network of EU FDI

In order to create the network, a bipartite graph has been generated, where the nodes are both investors and host countries; a link is drawn if a parent company invests in a certain host country. As usual in this literature, we project the links on two subspaces so that two new projected networks are obtained: the network of investors, and that of countries. We first analyse the whole set of firms, than we focus on three sectors: Textile, Machinery and Coal[3]. These sectors are relevant in the global value chain both in terms the number of projects and their value. As in De Masi et al. (2013), the choice of these three sectors allow us to show that firms are heterogeneous within the same sector as well; this means that heterogeneity is pervasive. In what follows, focusing on the three sectors identified above, we will try to understand:

1. the geographical patterns;
2. what are the main hubs (countries/firms) within the sectors;
3. the presence of subnets;

[3]Differently from De Masi et al. (2013), in this paper we have information of the specific sector of the projects and not of the investors

4. whether the main actors present specific features, and the characteristics of their projects.

In Tables 1-4, we report descriptive statistics both for the whole database and the selected sectors. Within the whole database there are 1586 and 2984 investors in 2003 and 2015 respectively, and corresponding 3141 and 5235 projects respectively. On average, an investor has 2 projects in 2003 and 1.7 in 2015, but we register large heterogeneity across the sectors with a minimum equal 1 and a maximum equal to 32 in 2003 and 75 in 2015. The topological measures of the bipartite graph for the whole sample disclose a large increase of both degree and strength (Table 3). It has to be noted that in 2003 the node with highest strength is a company from a traditional sector (Chemistry), whereas in 2015, the highest level is achieved by a company in Service sector (Serviced Office Spaces, Virtual Offices, Co-working Spaces). Moreover, as evident from Table 4 there has been a reduction in the betweenness centrality indicator between the two years considered (0.001 in 2003 and 0.0003 in 2015) whereas closeness centrality remains constant at 0.05. This is due to a change of investor network structure: in 2003 it consists of an highly compact cluster, while in 2015 several connected clusters emerge, producing a decreasing of the average value of betweenness but keeping the closeness centrality pretty constant. We identify the hubs using centrality measures. It is worth noting that looking at the whole network, while in 2003 the leader is a worldwide structured firm of the Coal sector with interests in almost all countries, in 2015 the leader is a firm of the service sector (sub-sector rental and leasing) with a focus on retailing. Adding this element to what we have found looking at strength, we can confirm that there has been a change in the leading sectors from 2003 and 2015: specifically, manufacturing has given way to service.

Table 1: Number of nodes and projects: projected investor network

Sector	Year	Nodes	Projects
		(Investors)	
Whole Sample	2003	1586	3141
Whole Sample	2015	2984	5235
Coal	2003	49	128
Coal	2015	36	73
Text	2003	51	64
Text	2015	42	67
Mach	2003	101	159
Mach	2015	323	455

Network analysis allows the identification of leaders because of their centrality value, while through the Kamada–Kawai algorithm ex-post common strategies can be detected,

Table 2: Most connected countries (hubs) in all sectors networks and sector by sector networks.

All	All	Coal	Coal	Mach	Mach	Text	Text
2003	2015	2003	2015	2003	2015	2003	2015
CHN	USA	MEX	GBR	CHN	USA	CHN	USA
RUS	CHN	RUS	CHN	BRA	CHN	BGR	CHN
BRA	IND	USA	IND	USA	DEU	BRA	ESP
USA	GBR	IND	MEX	GBR	IND	HKG	FRA
ESP	DEU	DEU	RUS	IND	RUS	HUN	DEU

without any ex-ante hypothesis on the existing relationships. Hence, we are not only able to identify the main receiving countries but also those countries that share many *projects* with their neighbours; by way of example, we can see that companies investing in US have also projects in China and so on.

Looking at the geographical distribution of affiliates (Table 2), two main markets of destination emerge in 2003: US and China. These were closely followed by the UK, Germany, France, Hungary, Czech Republic, Russia, India and Poland. On the other hand, in 2015, UK is the main market of destination, surrounded (not surprisingly) by US, China, Germany and France, that are now flanked by Spain, Australia and Mexico. Therefore, there is a change in the projects' flow from *European new comers* (with the exception of Romania) to countries outside the EU.

Table 3: Degree and strength measures: projected investor network

Sector	Year	Nodes	Degree			Strength		
		(Investors)	Mean	St. dev.	Max	Mean	St. dev.	Max
Whole Sample	2003	1586	120.5	121.2	883	205.7	348.7	3979
Whole Sample	2015	2984	300.2	294.3	2057	463.2	748.6	16781
Coal	2003	49	3.9	3.6	22	6.7	9	58
Coal	2015	36	3.6	2.3	9	4.2	3.3	14
Text	2003	51	2.4	1.2	4	2.8	1.6	16
Text	2015	42	4.1	2.9	12	4.6	3.7	16
Mach	2003	101	11.0	9	38	13.5	12.5	61
Mach	2015	323	31.9	28.5	463.2	36.2	36.8	258

Table 4: Centrality measures: projected investor network

Sector	Year	Nodes	Degree Centrality			Betweenness			Closeness		
		(Investors)	Mean	St. dev.	Max	Mean	St. dev.	Max	Mean	St. dev.	Max
Whole Sample	2003	1586	0.08	0.08	0.56	0.001	0.003	0.04	0.5	0.1	0.7
Whole Sample	2015	2984	0.10	0.10	0.69	0.0003	0.002	0.05	0.5	0.1	0.8
Coal	2003	49	0.08	0.07	0.45	0.018	0.051	0.326	0.3	0.1	0.5
Coal	2015	36	0.10	0.06	0.25	0.005	0.015	0.071	0.1	0.1	0.3
Text	2003	51	0.05	0.02	0.08	0.001	0.002	0.008	0.1	0	0.1
Text	2015	42	0.10	0.07	0.29	0.004	0.016	0.072	0.2	0.1	0.3
Mach	2003	101	0.11	0.09	0.38	0.008	0.026	0.204	0.3	0.1	0.4
Mach	2015	323	0.10	0.09	0.45	0.005	0.019	0.212	0.4	0.1	0.5

5 A focus on Three Sectors

As stated above, we focus only on three manufacturing sectors (Coal, Machinery and Textile) that seem to us representative of the FDI activities and allow us to qualitatively analyse both the structure of the network and behaviours of leaders.

5.1 Coal

As for the coal sector, Table 1 shows that both the number of investors and affiliates is reduced between 2003 and 2015. This may be due both to the merging process (of affiliates and investors) and it could be due to an increase in near-shoring.

Comparing the key destination countries of Coal investors (see Table 2), we notice a slight change between the two periods considered. While in 2003, the largest recipient was Mexico (followed by Russia, USA and India), in 2015, Great Britain was the most important country, followed by China and India, with Mexico and Russia.

In the Fig 2 and 3, the graphs projected on Coal firms are represented. The network has clearly changed between the two periods. Using the Kamada-Kawai layout algorithm, we find the key players of the industry at the hearth of the network. In 2003, the presence of a key player is evident; the network hub is not only present in many markets but also indirectly connected with other investors. Indeed, its largest number of projects (32) were done in 2003. The key motivations that this investor puts forward to explain these results have been, among the others: the domestic market growth potential, the proximity to markets or customers, and skilled workforce availability. Moreover, in 2003, the most important area of destination for the main hub has been Asia-Pacific, followed by North-America. The 2015 network is very different especially because of the presence of several segmented subnets. The 2003 leader is still present and important, but only for a subnet. We also register an additional subnet, with its own leader, and four other small networks. The change of structure is not surprising because Coal's investors build partnerships to lower international transaction management costs. This generates concentrations, by groups, in the same countries, as it is evident also from strength values reduction (Table

3), which declines from 6.7 to 4.2 between 2003 and 2015. Moreover, not surprisingly, the key players have reduced (but not eliminate) the projects soon after the crises.

Figure 2: Projected Network for Firms: Coal 2003

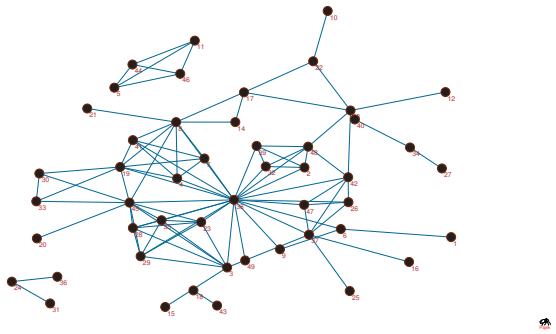
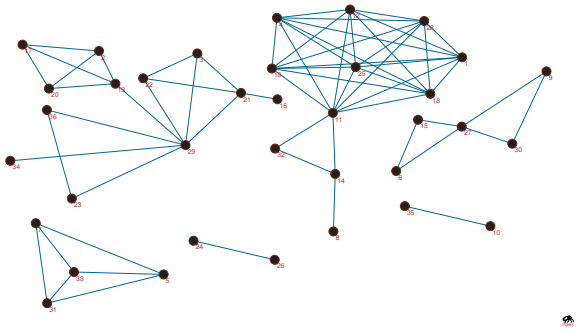


Figure 3: Projected Network for Firms: Coal 2015



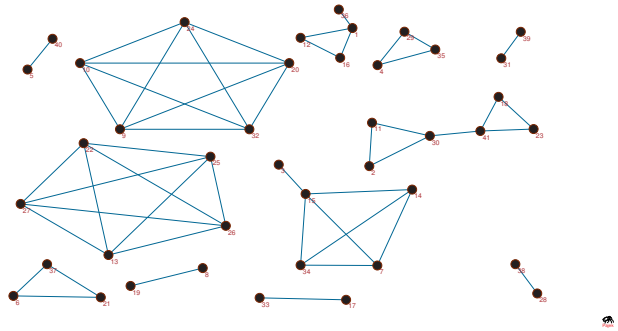
5.2 Textile

Table 1 shows that both the number of investors and projects, in the Textile sector, have remained constant in 2003 and 2015. However, the major destination countries have changed. In 2003, priority is given to developing countries such as China, Brazil or eastern European countries such as Bulgaria and Hungary. In 2015 instead, in addition to China, the main destinations are all developed countries: USA, Spain, France and Germany. As for the Coal sector, we can imagine that post-crisis internationalization strategies have led companies to turn to closer markets.

Looking at betweenness (Table 4), it is noteworthy that the textile sub-network has much lower values than the other two sectors. This means that it is difficult to identify large hubs or, more precisely, that businesses are fairly segmented and divided into groups. At the same time, average closeness increased in 2015 compared to 2003, indicating the emergence of relevant hubs in the network and a more interconnected network. Closeness is doubled between the two periods taken into account.

The Figures 4 and 5 represent the graphs projected on firms of f the textile sector. As in the case of Coal, also this network has clearly changed between the two periods. In 2003 the investments are more related to manufacture, but progressively the increasing number of retailers creates new links between nodes that were previously isolated. It is evident that the 2015 net is more connected, at least in the central part. There are still islands but a large group of firms moves together and on the same markets. This is also evident from the increasing values of both degree and strength from 2003 to 2015 (Table 1), the mean strength moves from 2.8 to 4.6.

Figure 4: Projected Network for Firms: Textile 2003

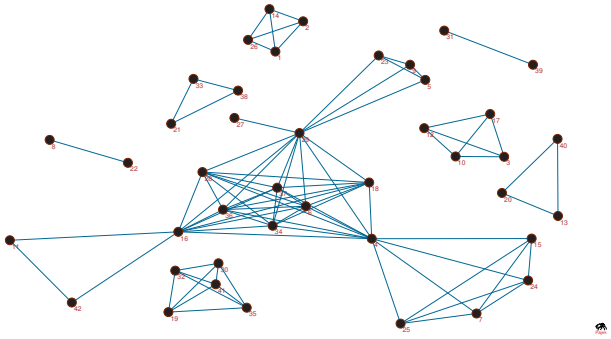


The most connected nodes (in terms of both degrees and betweenness) of 2003 engages in the design, development and manufacture of footwear products. And they mainly operate abroad as retailers. In that year, China and USA are the most important countries of destination regarding both job created and value of investment. On the other hand in 2015, the two emerging main leaders are focused on manufacturing textile products. Moreover their projects are related to sales, marketing and logistic.

5.3 Machinery

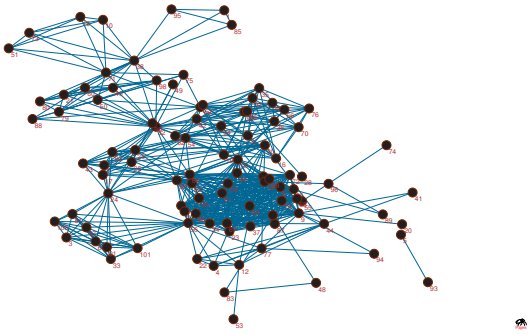
The last sector we analyze is the machinery sector. This sector presents the largest number of investing and affiliated companies. Moreover, the number of both investors and affiliates triple.

Figure 5: Projected Network for Firms: Textile 2015



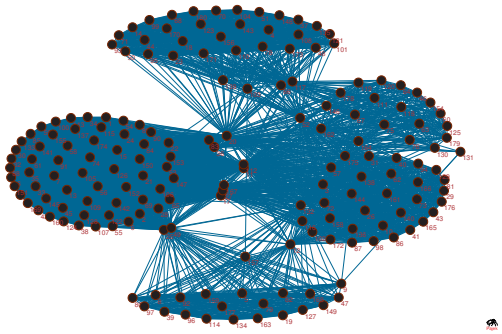
In a forthcoming work, analyzing the evolution of the network, we try to analyze and understand what this increase is due to. At present, we can imagine that it may be due to several factors such as the greater integration of EU countries, following the enlargement to the East in 2004 and 2007. The increase could as well be a response to the crisis: more fragmentation of production makes it possible to diversify risk and reorganize production. Or it could be just a structural behaviour of the industry as it is a highly connected sector. The betweenness do not reach the levels of the Coal sector, but the closeness is higher, indicating greater interconnection in the network. This emerges clearly from Fig 6 and 7, where the networks for the two considered years are reported.

Figure 6: Projected Network for Firms: Machinery 2003



It is really hard to unambiguously detect the leader of the network, since firms are very close among each other. Their maximum degree is high (38 in 2003 and 146 in 2015), as well as their strength and their betweenness, which are much higher than those of the textile sector, indicating the worldwide character of these firms. Moreover, sector leaders

Figure 7: Projected Network for Firms: Machinery 2015. For this particular network plot, we removed links with a weight lower than the median of weights in order to have a clearer picture.



produce mechanical and electronic components and their projects are mainly related to manufacturing products.

6 Conclusions

In the last decades, exporting has ceased to be the unique mode of internationalization, and foreign investments have been changing the geography of production. Starting from the empirical evidence, international economists have stressed the role of heterogeneity among firms to account for the choice of different modes of internationalization. We argue that heterogeneity is pervasive, regarding not only productivity (as in the Melitz's model) but all the main firm's characteristics such as innovation strategies or financial robustness. Recently, authors have shown that heterogeneity is also present within firms in the same sector (i.e. De Masi et al., 2013). Therefore, its deeper comprehension, could improve both policy makers and firms' understanding about the evolution of fragmentation of production.

In line with De Masi et al. (2013), we use the network theory to detect different foreign investment strategies among EU firms. Networks allow the reconstruction of connections between different individuals / agents / businesses. To the best of our knowledge this tool has been underestimated in the context of FDI. However, it allows us to highlight the relation between firms, and to single out the hubs, the 'leaders' in our acceptation, focusing on common or heterogeneous patterns in the process of internationalization. Moreover, it allows to empirically detect and, therefore, analyse the strategy used by the main actors of the network.

We reconstruct and discuss the network of European (EU28) foreign investing firms,

relying on information from complex network analysis. Keeping in due consideration both sector and countries of the destination, and without ex-ante priors, we singled out the linkages among investors. Three sectors have been selected (Coal, Machinery and Textile) for our analysis.

Moreover, using network indexes and examining the projects, we highlight the evolution of network's structure, in terms of both countries of destination and activities of the main 'leaders'. We used data from the 2003 and 2015, trying to compare the structure before and after the crises. Overall, considering all the sectors aggregated, we observed a structural change from 2003 to 2015 in the direction of formation of sub-networks or clusters. This can be due to the diffuse feeling of confidence dominating before the crises and leading to broad range investments. This has changed after the crises producing more prudent investment strategies, which are mostly directed to some specific countries.

This is particularly evident for the Machinery sector, that most probably experience near-shoring of manufactures and for Coal, where we observe both merging and near-shoring phenomena after the crises. The opposite behaviour is observed for the Textile sector; this can be easily explained by the increasing tendency to invest not only in manufactures but more and more in retailers.

In a future work, we will study the entire period, analyzing the evolution of the network year by year and focusing the analyses on each relevant sector, and on the amount of investment and the jobs created.

Furthermore, future work should be aimed to identify how specific crises in the industry, in particular the 2008 recession, impacted on FDI strategies in the selected industries and on their network structure.

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