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Giulia De Masi, Giorgia Giovannetti, Giorgio Ricchiuti

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Dipartimento di Scienze Economiche, Università degli Studi di Firenze
Via delle Pandette 9, 50127 Firenze, Italia
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Comments are Welcome

Abstract

In this paper, using the database ICE-Reprint, the network of Italian firms investing abroad is studied. This analysis focuses on some manufacturing sectors, highlighting the linkages among firms and detecting the key nodes of the system (both in terms of firms and countries of destination). Moreover, through the examination of affiliates' economic activity, different policies of internationalization among leaders emerge.

Keywords: FDI, Economics Networks, Projected network
JEL: F2, L1

1 Introduction

The recent and large literature on globalization has highlighted as heterogeneous firms in developed countries adopt different ways to tackle the changing international context: some with quality upgrading, others employing migrants, splitting production in different countries or merging with foreign firms and/or establishing subsidiaries abroad. Focusing on outsourcing and exploiting the idea that the economic system is a natural network, we want to reconstruct and analyze the network of the Italian firms investing abroad. Different sectors are investigated and the different strategies of investments are analyzed, to highlight heterogeneity. To the best of our knowledge,this study is the first application of graph and network theory to Italian Foreign Direct Investment (FDI).

Triggered by the opening up of international markets, production networks have moved to a multi-country dimension. As a consequence, firms have modified their internationalization strategies making them more complex. In Italy the empirical evidence at macroeconomic level suggests a low ability of domestic firms to penetrate foreign markets through FDI, especially during the last decade. This low multinational activity intensity is usually explained by the highly fragmented industrial structure, and by the small firms size, which makes it more difficult to fragment production and, especially, to buy foreign firms ([1], [2]). Moreover, there is a strong heterogeneity among firms in terms of productivity, size and of the characteristics of the investments done abroad both regarding countries of destination and modes of internationalization. Modeling through network analysis these relations allows us to pull out information that usually does not come out: mainly we are able to distinguish whether the strategies of internationalization depend on proximity (at sector, and geographical level) among firms, and emphasize the existence of differences between productive and commercial investments.

In the last decade, the analysis of complex networks has received great attention in both natural and social sciences [3]. Networks analysis enables the reconstruction of the links and the evolution of the connection between different individuals/agents/firms. Specifically, the main effort has been to understand the basic mechanism of communication networks: Internet, World Wide Web [4], e-mails network [5]. Each of these systems is formed by a set of agents that interact and compete receiving reciprocal advantages. This approach is promising for the study of economic systems where firms, households, individuals and the State act actively together, shaping without solution of continuity the relevant socio-

economic structures. Network analysis is able to reproduce stylized facts, with simple models related to stationary and non-stationary contexts.

Given recent improvements in computer science, these topics, initially analyzed in a game theoretic framework, have been recently developed using graph theory. Specifically, through networks the interactions are quantitatively analyzed by means of topological indexes. Pioneering empirical works in economics are related to the financial markets structure [6], the European firms' network [7] and the relationship between firms and banks [8] and flows of international trade ([9], [10], [11]).

We use the dataset ICE-Reprint (at the moment the only database with Italian FDI) for 2005, to derive a bipartite graph where the nodes are investors and countries of destination. The topological structure depends on some characteristics: the same industrial sector, the same province or doing investments in the same countries. Given the network dimension - there are 2934 investors, more that 137 countries of destination and 11000 affiliates - the analysis is focused to subsets of manufacturing (wearing and textile, electrical energy, mechanical and electrical machineries) to understand:

1. whether the internationalization modes depend on proximity (at sector, and geographical level);
2. what are the main hubs (countries/firms) within the sectors;
3. what are the strategies employed by the main actors (firms);
4. whether the main actors are the biggest firms.

This information can help to develop a better focused industrial policy. Indeed, the main concerns on the effects of globalization regard the safeguard of both national production and employment (within the country).

2 Method

The network analysis allows to investigate the topological properties of the complex structure of economic relationships. The nodes are Italian investors and host countries. A link is drawn if a particular investor goes in a particular host country.

Many tentative studies have been done in the field of bipartite graphs ([12], [13], [14]). The main statistical quantities under study 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. Moreover, we can extract from the overall network, two networks, each one composed by just one kind of nodes. This 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.

A network is represented from a mathematical point of view by an adjacency matrix. The element of the adjacency matrix a_{ij} indicates that a 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

$$k_i = \sum_j a_{i,j} \tag{1}$$

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 ($d_{ij} = 1$). Using the adjacency matrix this can be written as

$$d_{ij} = min\{\sum_{k,l \in \mathcal{P}_{ij}} a_{kl}\} \tag{2}$$

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

$$dc_i = k_i/(N-1) \tag{3}$$

A second one 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 (also called distance $d(i, j)$). This quantity is called **site betweenness** $b(i)$ and is usually defined by

$$b(i) = \sum_{\substack{j,l=1,n \\ i \neq j \neq l}} \frac{\mathcal{D}_{jl}(i)}{\mathcal{D}_{jl}} \tag{4}$$

where $\mathcal{D}_{jl}$ is the total number of different shortest paths (distances) going from j to l and $\mathcal{D}_{jl}(i)$ 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**

$$cl(i) = \frac{N-1}{\sum d_{i,j}} = \frac{1}{\bar{d}} \tag{5}$$

which is the reciprocal of the average distance from that node to the other nodes (see [15] [16] and [17]).

2.1 Projected network

In the study of bipartite graph a very widely used approach is to separately study two networks that can be defined from the original network. If we call the two kinds of nodes as 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 ([12], [13], [14]).

In the present study the network of investors and the network of countries are defined, where the former is the network of Italian parent firms investing in the same country and the latter is the network of countries where firms invest. Considering the set of investors and countries $I = 1, 2, 3, 4$ (squares) and $C = a, b, c, d, e, f$ (circles), the network projected into the subspace of firms (left panel) corresponding to the network of countries and firms is plotted in Fig 1.

In projection process, information on how many countries are jointly chosen by two different investors would be lost. In fact, two firms may have a link regardless if they have only one country in common and more than one. To retain this kind of information, a weighted network is defined, associated to a weighted adjacency matrix W: the weight associated to the link between two firms is the number of common countries they chose. Therefore, starting from the adjacency matrix of investor-country relationships $a_{i,c}$, the general element of the matrix W is given by

$$w_{i,i'} = \sum_{c,c'} a_{i,c} \cdot a_{i',c'} \cdot \delta_{c,c'}. \tag{6}$$

Two investors are linked if they invest in at least one common country. The link is weighted and the weight represents the number of common countries where they invest.

$$m_{i,j} \leq min(k_i, k_j) \tag{7}$$

3 Data

The ICE-Reprint database is the census of foreign affiliates of Italian firms (with a turnover higher than 2.5 millions euros) in manufactures and services but excluding some financial sectors (i.e. banking, insurance, financial services) are not included. The survey concerns equity (joint venture, participation with affiliates) but not non-equity operations. The Census has relevant information both on Italian investors and affiliates: sales, number of employees, country of destination, industrial activity (for details, see [2]). For the division into industrial sectors, the version of the classification of economic activities ATECO (the Italian classification for NACE rev.2 adopted by the Italian Institute of Statistics) proposed in 2002 is used.

In Table 1, main statistical quantities regarding the whole database and selected sectors (wearing, textile, energy and machine and mechanical and electrical machineries) are reported. As already mentioned we consider 2934 investors from 94 Italian provinces, with 11023 affiliates distributed in 137 out of 199 countries. In the manufacturing sector on average, each investor has roughly four affiliates, with interesting differences among the selected sectors.

It is worth noting that, on average, firms that invest abroad have more than 500 employees and sales are above 600 million euros. However, sectors are highly heterogeneous. Firms in wearing and textile are small and medium size: just 10% has more than 1000 workers. Moreover, the average sale is low in comparison with the average of the sample: 36 against 45 millions of euros. On the other hand, in energy sector (as well as those of chemical products and auto vehicles, non reported here) firms are substantially larger both in terms of sales and of employees.

Looking at the geographical distribution of affiliates, the three main markets of destination are USA, Germany and France, followed by Great Britain and Spain (Table 2). It is interesting to note that new EU countries, namely Romania, Poland and Hungary rank second and Brazil and China follow closely. In Romania outsourcing is due mainly to small and medium size firms of textile and mechanical.

4 The Network of Italian FDI

The intrinsic firms' heterogeneity implies the adoption of different internationalization strategies. The network analysis allows us to capture and investigate those

differences. As already noted, the nodes of the whole network are both Italian investors and host countries: it is a bipartite graph and a link is drawn if a particular investor goes in a particular host country.

However, given the huge number of both nodes and links,from the overall network, two sub-networks are extracted, each one composed by just one kind of node. In particular, two networks are defined: the network of investors, i.e. Italian parent firms investing in the same country, and that of countries, i.e. countries where the same firm invests. In Figure 2 and 3, we considered the projected networks of firms and countries respectively (all figures are developed with [18]). To achieve a readable representation, we consider just firms that have the highest number of links, as for all graphs below. The Kamada-Kawai algorithm, particularly efficient in highlighting connections among groups has been used. It represents the graph as set of harmonic oscillators, plotting in the middle of the figure those nodes (firms or countries of destination) with the highest number of edges and putting closely more connected nodes.

In Figure 2, the core of the projected network of firms is represented by the leaders in the sectors. The core is composed by firms of sectors wearing and textile and mechanical. Indeed wearing and textile and mechanical have firms highly integrated: on average they have more than one affiliate in 30 countries. However, analyzing the activity of the affiliates (the kind of investment done by the investor), we note high heterogeneity. Firstly, commercial FDI coexists with production one. The former are located in large and strategic countries used as launch pad while the latter are usually in other countries of the same continent. On the other hand, there are both firms that invest abroad through horizontal or vertical FDI[1] and firms that invest in the most part of countries just through commercial activities or holdings (this interesting element may indicate the presence of local sub-contractors). Information related to different modes of internationalization exploited for a more efficient industrial policy. Indeed, the effects on both employment and firm's performance strictly depend on the intensity of firms' international integration.

Figure 3 depicts the projected network in the sub-space of countries. To detect the most important countries we highlighted a link between two countries if there are at least 500 investors in both countries. The core of the network is composed by USA, France, UK, Spain and Germany: where USA is the highest hub

[1] while with horizontal FDI a multi-plant firm duplicates the same activities in different countries, with vertical FDI a firm locates different stages of production in different countries.

but Germany is the node with the highest clustering coefficient. The connections around Germany are really dense (nodes linked with Germany are linked each other) meaning that Germany is a key country to understand Italian FDI: it is geographically close, has similar rules and standards and these characteristics make it easily reachable even for small-medium firms. Other important destination markets are other EU countries and the emerging markets Brazil, Argentina, China and India. This preliminary analysis allows us to detect the key markets of Italian firms but also those for which Italy is still lagging behind in comparison with its competitors.

In order to investigate strategies of investors, is studied the investor network, obtained from the projection of bipartite network in investor space. Statistical measures have been performed on investors network, like degree, clustering coefficient and the three measures of centrality, that provides different information on network structure: degree centrality, betweenness centrality and closeness centrality (Table 3).

All statistical measures have been compared with the analogous ones for networks generated by a null hypothesis criterium (between parenthesis in Table 3). In particular, for each considered bipartite network, a random network with the same degree sequence is generated, randomizing links from investors to countries. betweenness and closeness centrality values have been compared. Obviously, the degree measures are equivalent. Afterward, the projection to investor space has been formed. The resulting network is compared with the investor networks obtained from projection of original bipartite networks.

Results from bipartite network show that closeness centrality is very similar to the null case network (see Table 4). Instead, betweenness of Wear and Textile and Mechanical networks is sensitively higher than the null case. This is an evidence that in the real network there are many nodes in the center of small communities. This role is played on one hand by some countries (i.e. Germany) that are preferably chosen for FDI by Italian firms and, on the other hand, by large firms that have largely differentiate their investment foreign markets.

The most relevant difference are related to investor networks. For all sectors, the betweenness is lower than in null case, while degree, clustering coefficient, closeness centrality and degree centrality are higher than the randomized networks. The degree centrality of observed network is higher than the randomized network: this is due to the fat tailed distribution of degree, like shown in Fig (4), cleared off by randomization. This is an evidence of the role of few nodes that are hubs of the networks with many peripheral nodes.

Clustering coefficient higher than random case is a clear evidence of pres-

ence of common strategies (in particular common countries of investment) among groups of investors. The same is confirmed by higher closeness centrality that highlights also the presence of a strong core of countries preferably chosen by investors of the same sector, varying only few countries of investment. The low betweenness can be explained by the high level of heterogeneity present in real network, that is cleared off by the randomization: from Fig (5) a fat tail scaling law emerges. This an evidence of the important role of hubs that connect many peripheral nodes. Hubs can be considered the leaders of sector, surrounding by small strategy followers.

In table 5, we report correlations between degree and betweenness and some measure of size (sales, number of employees) for the sectors we have analyzed. It is worth noting that for wearing and textile the values are greater than those for the average: the larger the firms, the connected, the more relevant is their role in the specific industrial network. This result seems to confirm, even if indirectly, the analysis of [1], who claim that firms which are more internationalized are the largest.

4.1 Wearing and Textile

Given nearness, the wearing and textile sectors have been merged. It is worth noting the simultaneous presence of large and small-medium enterprises: 36% of firms have less than 50 employees and 20% less than15. The smallest firms invest predominantly in the European Union. Romania is an important attractor of these investments: roughly 50% of investors have less than 50 employees and half of these have less than 15 employees. Particularly, analyzing the activity of the affiliates it seems that investments are done to reduce costs of production rather than to supply the neighboring exporting markets. Table 3 reports some topological measures of the sector, which give us important additional information with respect to the simple descriptive statistics. The Closeness is high, indicating a strong density between nodes (firms). Finally the sector's betweenness (the average of the individual betweenness) is low: there are many key actors in this subspace[2]. In general there are many common countries of destination and, as a consequence, homogeneity in the strategies adopted.

[2]the information on the closeness and betweenness is an important Value Added of Network Analysis for Economics, because allow us to 'weight' the importance of geography and real role of firms/countries

In Figure 6 and 7 we plotted the projected network for firms and countries of destination, respectively. In the network of firms, two elements emerge clearly: a key player and a group of firms (up in the right in the graph) which have similar choices, in terms of countries of destination. Hence, the network has a leader which has affiliates in the most important countries and is trying to enter new markets. More precisely, looking at its affiliates, we note that most are holdings, maybe signalling the use of subcontracting as strategic policy. On the other hand the group of medium-large enterprises concentrates the presence in some specific markets (North America and West Europe). Moreover, their strategy of internationalization is unambiguous: they produce in one or at maximum two countries in the same subcontinent, and have one or more commercial offices in other countries of the same area. Their outsourcing activity is, therefore, used as platform to export in the neighbour countries. This result is crucial to evaluate the effects of FDI on the Italian economic system, because it seems that these firms do not invest abroad on the grounds of cost-saving but to enter new markets (as bridgehead) to improve the performance of their exports.

It is interesting that the fundamental nodes, in Figure 7, are again USA, France, Romania and Germany. In all these countries Italian firms have both commercial and productive activities. Moreover, there is a good presence of affiliates even in Japan and Hong Kong, with just commercial activities, and China with recent and growing productive activities. These patterns seem to confirm the existing anectodical and statistical evidence in Italian textile small multinationals (see [2]).

4.2 Mechanical and electrical machineries (Mechanics)

More than 20% of Italian manufacturing firms investing abroad belong to the mechanical sector. They are small and medium enterprises: 75% have less than 250 employees and one fourth less than 50. On average a firm has 10.4 links and the number of links, as expected, is correlated with firms' size, both in terms of sales and employees as evident in Table 5. Firms in this sector invest in 83 countries with a strong presence in China (118) and Brazil (112) as well as in farther countries, such as Australia (38).

Figure 8 reports the projected network of investors. In the middle of the graph, we clearly detect three key nodes of the network: two firms producing mechanical devices and the last electrical machineries. These three firms produce just in two/three countries and have commercial activities in neighboring countries, so that FDI are mainly market seeking investments. As well as these leaders there are other firms (all in the sub-sector of electrical machineries) which have done

vertical investments mainly in developing or emerging countries such as China and Brazil.

The projected network of countries of destination (Fig. 9) shows two different groups: leaders (the pentagon in the middle) and followers (Sweden, China, Brazil and the Netherland). A relevant difference between these two sets emerges. In the first group (with the notable exception of Germany and US), investors have just commercial activities. On the other hand, in the second group there are mainly productive investment (both horizontal and vertical) and the commercial activity is just a by-product.

4.3 Electrical Energy (Energy)

The sector of electrical energy presents, given the obvious effects of scale, the largest firms (both in terms of sales and employees, see Table 1), the lowest number of firms (26) and the largest number of average affiliates for investor (14). The average degree is 4.9, detecting a greater dispersion of investments among countries of destination in comparison with the other two sectors considered. The closeness is low, while the betweenness is the biggest. This information suggests the presence of a dominant node (investor): differently from the other sectors where we found several leaders (see Figure 10). Indeed, 56% of affiliates belong to the same firm, linked to all the others, with significant presence in North and South America, and Spain. Its affiliates either produce and distribute energy or operate in sub-sector of services for electrical energy (mainly in US). However, there is even in this sector a second group of important players, whose affiliates mostly distribute energy. It is worth noting that while the leader is present in all continents, the activities of these firms are geographical concentrated in a key country (Argentina rather than Netherland). Finally, the key countries of destination for these sectors are those characterized by liberalization of both production and distribution of energy: mainly US and UK (Figure 11).

5 Conclusions

While some years ago trade was the most important mode of internationalization, nowadays firms are characterized by more complex strategies. In Italy firms with a complete net of affiliates (for production or commercialization) are still few (and concentrated in some sectors). At the same time the internationalization has been associated with a strong reorganization of the production both within and between

countries. Uncertainty linked with globalization has made aware politicians, businessmen and citizens that it is crucial monitoring constantly the evolution of the international markets, in order to analyze changes and minimizing the possible negative effects on the economic system in terms of domestic employment. In this paper, using the database ICE-Reprint, we study the network of Italian firms that invest abroad. To the best of our knowledge, this is the first study based on Complex Network theory. Our analysis focuses on some manufacturing sectors, highlighting the linkages among firms and detecting the key nodes of the system (both in terms of firms and countries of destination). Through the exam of affiliates' economic activity we can distinguish different policies of internationalization among leaders. Our study reveals a strong heterogeneity (inter and intra-industries) of strategies adopted. On the one hand there are firms that invest abroad (horizontal FDI) using middle-large countries as productive pad to export in neighboring countries through commercial affiliates. On the other hand, there are some global players, which make vertical FDI; their production is carried out for cost-saving reasons but also in search of professional qualities. Finally, most foreign activities seem to be linked to commercial purposes, hence in the attempt to promote Italian exports. This work has allowed us to analyze the foreign activities of Italian firms and principal countries of destination (among the others US, France and Germany). It suggests for which markets Italy is still late in comparisons with the other countries, an information which could be exploited to support an active industrial policy for Italian internationalization.

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Table 1: Descriptive Statistics

	Av. Sales	Av. Employees	N. of Affiliates	N. of Investors
Wearing	45.627	162	637	196
Textile	36.464	179	635	245
Mechanical	43.604	198	2156	617
Energy	1655.091	3076	361	26
All Sectors	610.656	552	11023	2934

Note: Authors' calculation from ICE-Reprint.

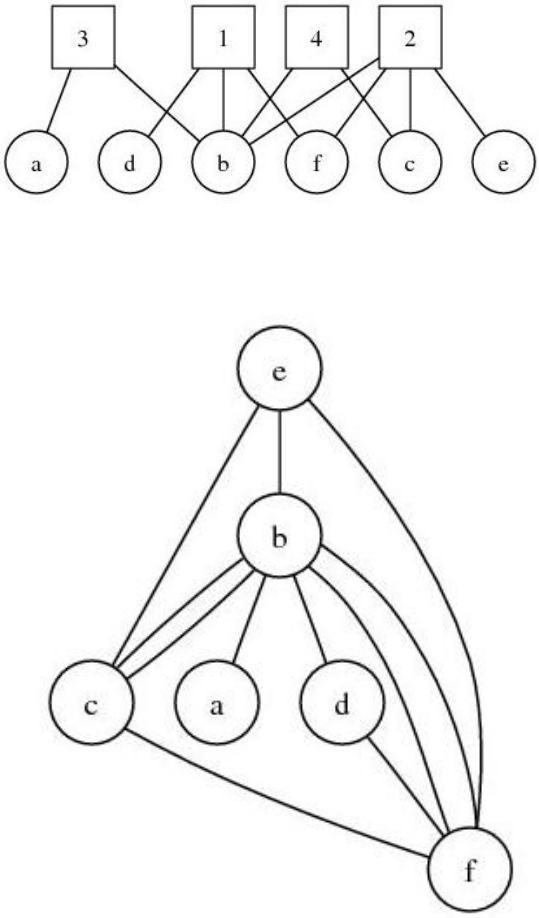


Figure 1: Bipartite graph and projected graph (one mode reduction on firms space). Countries of investment are square and parent firms circles.

Table 2: Ten main countries of Destination

Country	Number of Investors	Number of Affiliates
USA	763	1196
Germany	710	1028
France	706	1201
UK	554	838
Spain	475	733
Romania	404	468
Brazil	287	363
China	273	375
Poland	226	270
Hungary	155	189

Note: Authors' calculation from ICE-Reprint

Table 3: Some topological measures: Investors

	N. of Investors	Betweenness	Closeness	Clustering	Degree	Degree Centrality
Wearing and Textile	441	0.0001 (0.0008)	0.96 (0.77)	0.98 (0.92)	416 (294)	0.94 (0.67)
Mechanical	617	0.0001 (0.004)	0.97 (0.82)	0.99 (0.93)	591 (460)	0.96 (0.75)
Energy	26	0.004 (0.01)	0.93 (0.82)	0.96 (0.89)	24 (20)	0.93 (0.76)

Table 4: Some topological measures: Bipartite Graph

	N. of Nodes	Betweenness	Closeness	Degree	Degree Centrality
Wearing and Textile	521	0.003 (0.0003)	0.35 (0.37)	7.8	0.018
Mechanical	702	0.002 (0.0002)	0.45 (0.39)	10.4	0.017
Energy	86	0.02 (0.03)	0.36 (0.32)	4.9	0.19

Table 5: Correlation between topological measures and size

Sector	(degree,sales)	(degree, employees)	(betweenness,sales)	(betweenness,employees)
Wearing and Textile	0.52	0.49	0.37	0.38
Energy	0.02	0.07	0.02	0.06
Mechanical	0.66	0.66	0.65	0.61
All Sectors	0.31	0.34	0.64	0.38

Figure 2: Projected Network of firms: all sectors

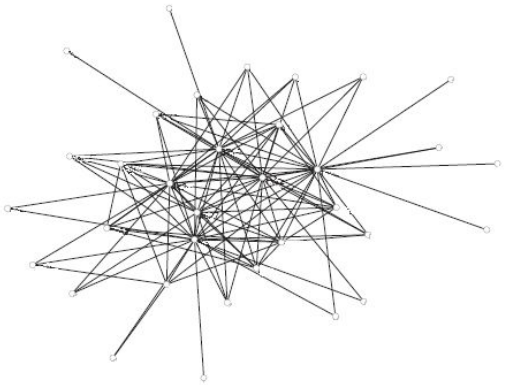
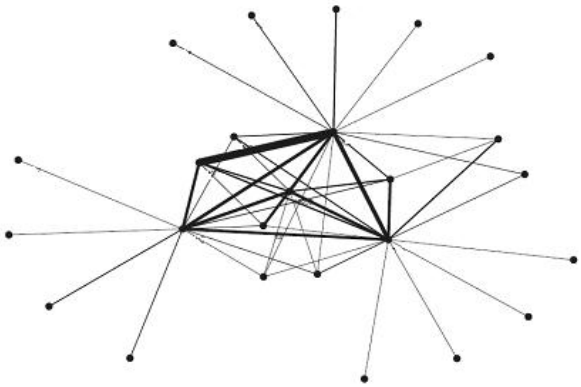


Figure 3: Projected Network for country of destination: all sectors



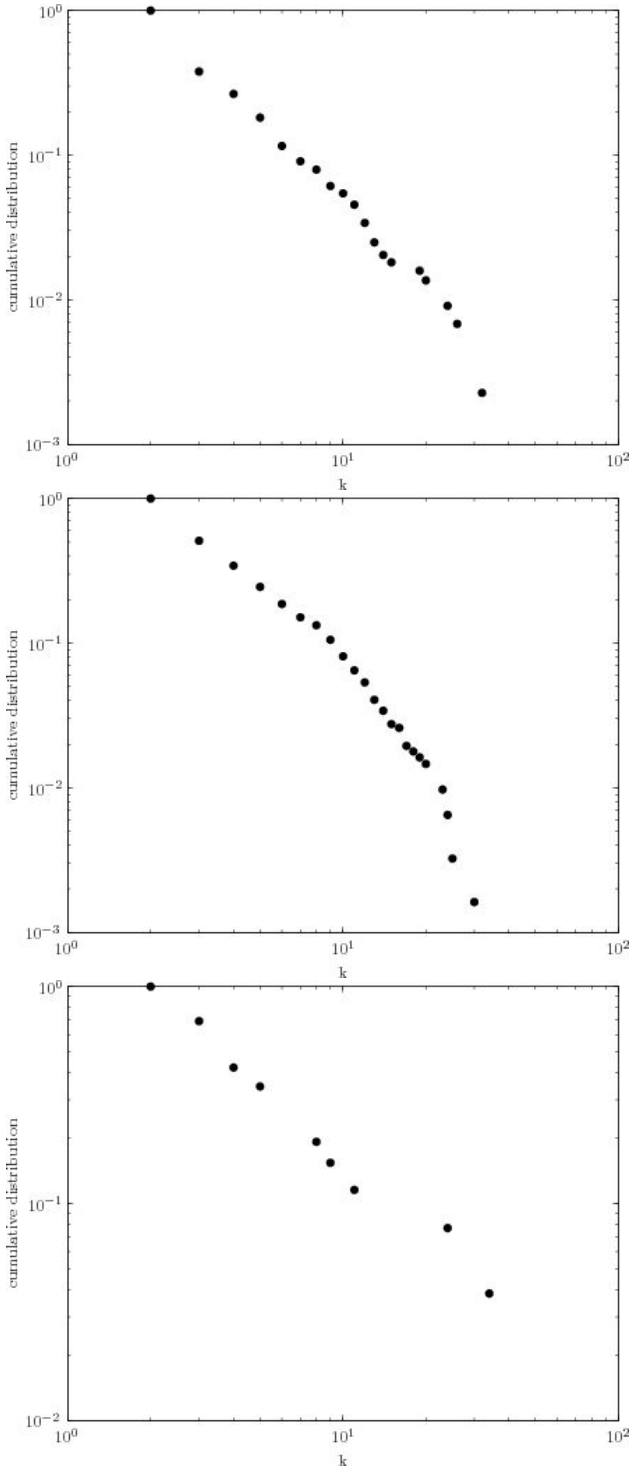


Figure 4: Comparison of degree for the mentioned sectors: wearing and textile, mechanical, energy.

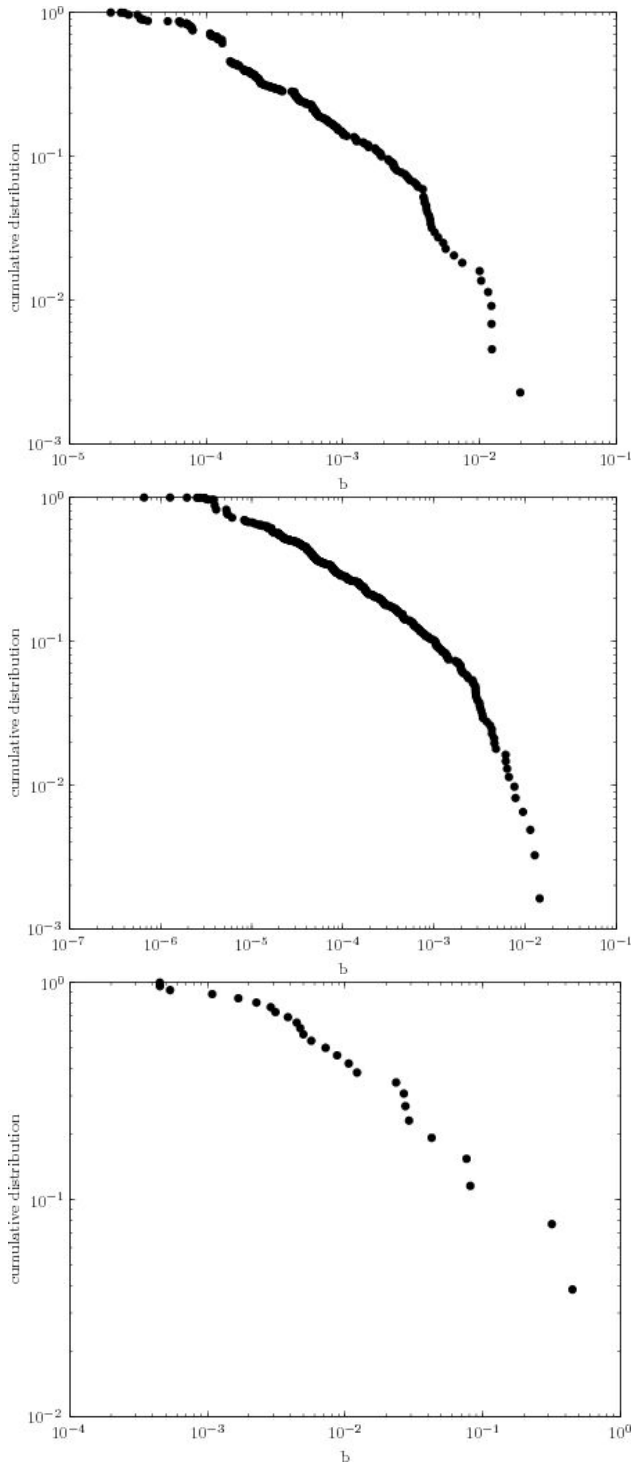
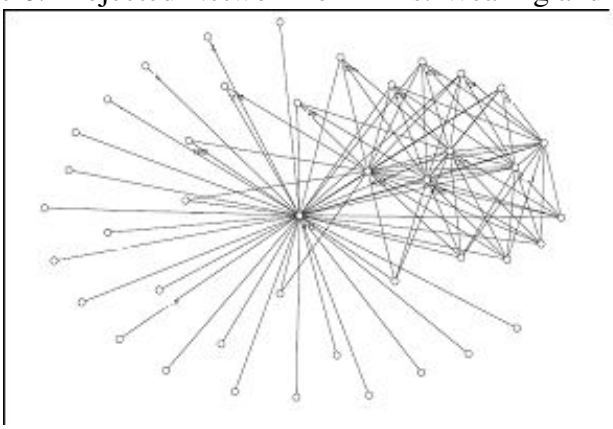


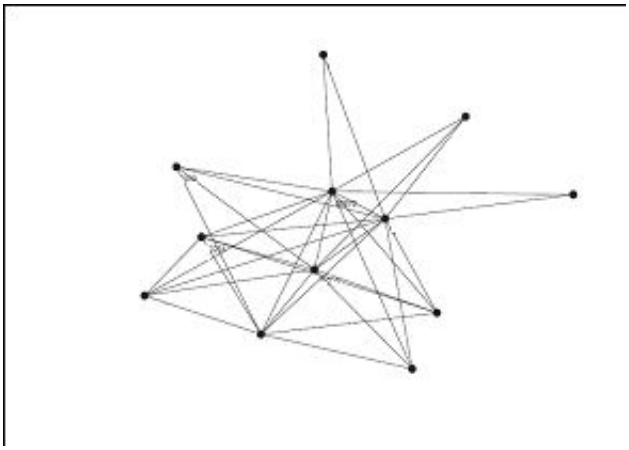
Figure 5: Comparison of betweenness for the mentioned sectors: wearing and textile, mechanical, energy.

Figure 6: Projected Network for Firms: Wearing and Textile



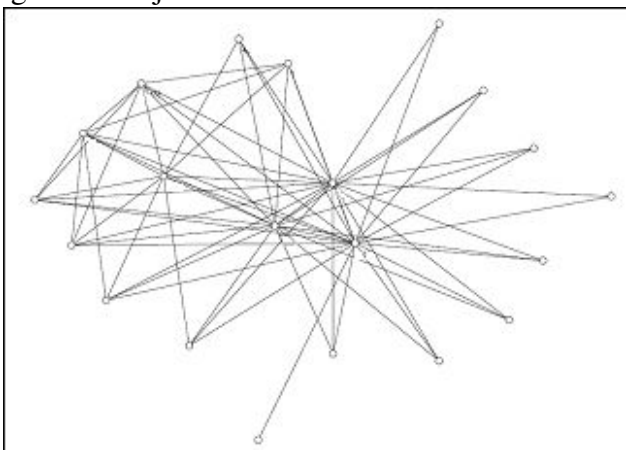
Note: to improve the visualization we removed both nodes and links with a lower weight (a lower number of countries of destination in common)

Figure 7: Projected Network for Countries of Destination: Wearing and Textile



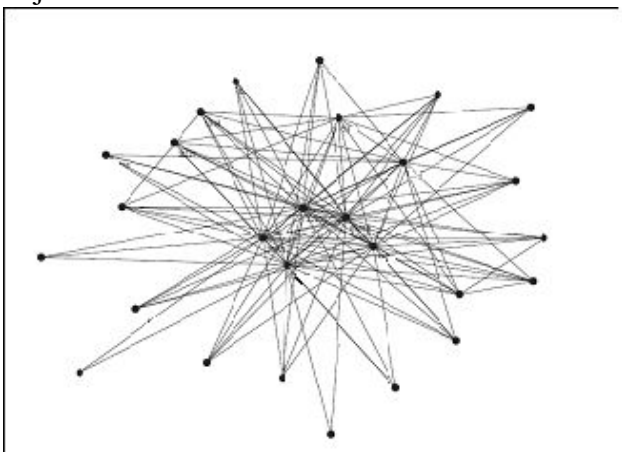
Note: to improve the visualization we removed both nodes and links with a lower weight (a lower number of countries of destination in common)

Figure 8: Projected Network for Firms: Mechanical



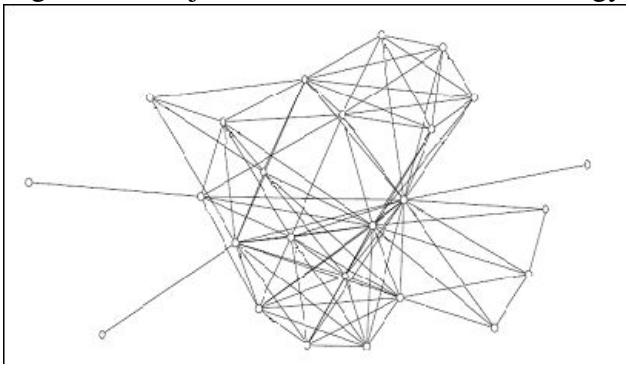
Note: to improve the visualization we removed both nodes and links with a lower weight (a lower number of countries of destination in common)

Figure 9: Projected Network for Countries of Destination: Mechanical



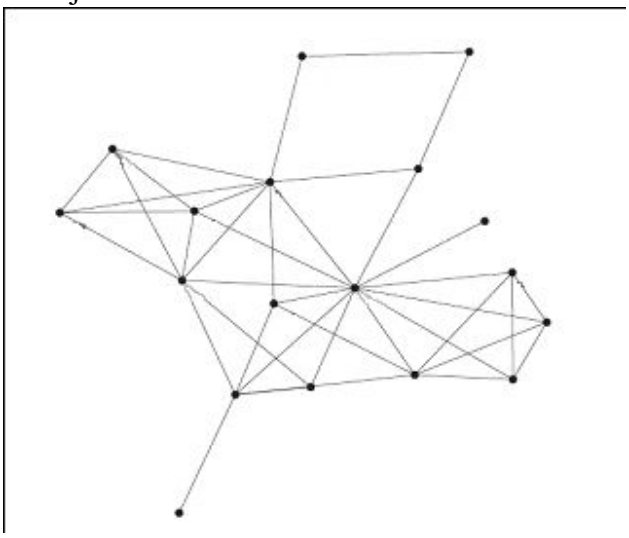
Note: to improve the visualization we removed both nodes and links with a lower weight (a lower number of countries of destination in common)

Figure 10: Projected Network for Firms: Energy



Nota: all investors

Figure 11: Projected Network for Countries of Destination: Energy



Note: to improve the visualization we removed both nodes and links with a lower weight (a lower number of countries of destination in common)