Aussenwirtschaft, 65. Jahrgang (2010), Heft II, Zürich: Rüegger, S. 167–189

# Comparing sectoral international trade networks

Luca De Benedictis* and Lucia Tajoli**
University of Macerata and Politecnico di Milano

This paper uses the tools of network analysis to assess the different characteristics of world trade in different manufacturing industries. The structure of the trade networks is compared to understand to what extent the world market characteristics differ between sectors. We find that in some sectors the structure of trade flows gives rise to a dense, widespread network with many links, while in others we observe a centered network, organized around hubs that centrally coordinate the flows. The results indicate a pattern of network structures, showing a positive correlation between the goods' complexity and the network complexity, changing the extent of the relevant market and its structure across goods.

*Keywords:* International Trade, Network Analysis, differentiated goods
*JEL Codes:* C02, F10, F14

## 1 Introduction

How is the structure of international trade for a given good organized? This question might have a distinctive answer according to the type of goods that are traded. The existing trade models suggest that for standardized goods potential partners can be many, but eventually only the one holding a comparative advantage (i.e. the one offering the best price) should be selected as an exporter. Therefore relatively few (unidirectional) trade links will appear between countries. Instead, for goods produced in many varieties and qualities, there will be many trading partners, and many multiple links will exist. Also for goods with low transport costs, partners can be numerous, and either far away or close, while for goods with high transport cost, geographic proximity of partners will be important, and partners will be spatially selected. In high-tech, sophisticated production, the technological proximity of partners can give rise to selected trade flows around a technologically-advanced center.

If we describe the structure of international trade flows as a network, we expect that trade in different types of goods would give rise to trade networks

* DIEF – University of Macerata – Via Crescimbeni 20, Macerata 62100, Italy. +390733258235, debene@unimc.it
** Dipartimento di Ingegneria Gestionale, Politecnico di Milano – piazza Leonardo da Vinci 32, Milano 20133, Italy. +390223992752, lucia.tajoli@polimi.it
The authors wish to thank participants to the 11th ETSG Conference in Rome for their stimulating comments.

with different characteristics. The shape of the network is influenced by the characteristics of production and demand, as the network is formed by the existing links between exporters and importers.[1] The role of countries in the network depends on their characteristics as suppliers (their comparative advantages, their size and factor endowments, etc.) as well as on their preferences as buyers of the goods, giving rise to arcs (or links between vertices) in the network. According to these specificities, for some products we should expect a dense, widespread network with many arcs, and for others a less dense network, possibly centered, organized around a hub that centrally coordinates the flows. The structure of the trade network in terms of density, centralization and clustering can have a direct impact on the competition between countries and on the formation of the international price for a given good, by defining the size of the market in terms of potential demand and supply.

In this paper we show that distinctive industries give rise to trade networks with diverse structural characteristics, as the theoretical framework of trade relations suggests. Network analysis indices are used to identify the characteristics of each trade network (Goyal 2007; Vega-Redondo 2007).

The results of this analysis are then used to characterize the market for different types of goods.

## 2 Goods' characteristics and trade links

A characteristic of economic networks is that they result from the behaviour and decisions of a number of self-interested agents. Assuming that a link between two vertices represents an economic transaction taking place, following Jackson (2005), economic networks can be seen as a representation of the equilibrium resulting from this set of transactions. This insight applies also to international transactions between countries. The basic insight of international trade models is that a trade link between two countries occurs to exploit price differences between them. According to trade models based on comparative advantages, the more different countries are, the more likely it is that they trade with each other (see for example Dixit and Norman 1980). Furthermore, under the most strict hypotheses of these mo-

1 The benefit of representing trade flows as a network is to give emphasis to the relationship between the countries in the network and to the structure of the system itself, which is the objective of network analysis. For a discussion on the applications of network analysis to international trade studies, see De Benedictis and Tajoli (2009).

dels, in the absence of transportation costs, in a framework where countries' sizes are similar, exports should come only from the country (or countries) that offers the good at the lowest prices. In this homogeneous goods context, in each industry the number of incoming trade flows observed for a given country should be limited, while outgoing trade flows would come from a subset of countries, and no bi-directional links are expected. This would give rise to a trade network with a relatively low density.

In the case of differentiated goods instead, the theoretical models suggest that we should observe trade also between similar countries, and trade in the same industry can exist in both directions between a country pair (KRUGMAN 1980). A preference for variety together with the possibility to exploit economies of scale in production will tend to increase the number of trading partners for each country. In the case of differentiated goods in fact, under the hypothesis of love-for-variety in the preference structure and of economies of scale in production of each variety, each exporter will try to reach as many markets as possible and consumers will tend to have a large number of suppliers, increasing the number of trading links of a country. In a model *à la* ANDERSON and van WINCOOP (2003), with homogeneous firms within each country and consumers' love of variety, this ensures that all goods are traded everywhere. In this model there is no geographical extensive margin, and any obstacle to trade such as distance or trade barriers affects trade volumes at the intensive margin. Therefore in such a context of differentiated goods, we should expect a very dense and even complete trade network, where every vertex is connected to all other vertices.

On the other hand, RAUCH (1999) suggests that for differentiated goods, the heterogeneity of manufactured goods in terms of quality and other specific characteristics at the base of the imperfect substitutability between them give rise to a matching process which is costly. Other models indicate that the cost of accessing to a foreign market can be relevant especially for differentiated goods. In the presence of fixed costs for exporting, theoretical models show that a sharp reduction in the number of trade links between countries is observed. If these costs are specific to the exporter-importer pair, the distribution of trade links can be very heterogeneous across countries. HELPMAN, MELITZ and RUBINSTEIN (2008) show that the combination of fixed export costs and firm level heterogeneity in productivity, combined with cross-country variation in efficiency, implies that any given country need not serve all foreign markets. Both the search and the access costs will tend to reduce the number of trade links for each country. Therefore, for differentiated goods we have an ambiguous result in terms of the expected

number of links: importers will try to have many inward trade links to benefit from variety, and exporters will try to have many outward links to exploit economies of scale. But if they have to bear the costs to access to foreign markets, they will have to select where they operate, and the number of links will be constrained by the extent of the search and entry costs.[2]

The above hypotheses suggest that the structure of the international trade networks should be less dense for homogeneous goods, and more dense for differentiated goods, even if the number of observed links will depend on the relative importance of searching and access costs with respect to the strength of economies of scale and preference for variety. This difference in network structure according to the goods' characteristics is the hypothesis we want to examine in the following section.

## 3 Differences in trade networks

In what follows, we look at countries as vertices in a network where arcs are given by their economic ties, measured by trade flows. The structure of the network arising from these trade links is the object of our analysis.

More specifically, we consider the networks created by trade flows of goods belonging to different industries. Our bilateral trade data are from the BACI database of CEPII, which is based on the UNCOMTRADE database. The database includes 222 countries, therefore our networks will have 222 vertices. The level of disaggregation we use corresponds to the three-digit ISIC code, or 28 sectors, and we analyze 28 distinctive networks.

We consider disaggregated bilateral imports for the year 2000. In each industry, each import flow is counted as one arc going from the origin to the destination country, independently from the value carried by the flow (in other words, arcs are unweighted in computing the basic network indices). Every arc connecting two countries is an export flow (or an outgoing link) from the point of view of the sender, and an import flow (or an incoming link) from the point of view of the receiver.[3] The database contains a total

2 The matching cost could also be borne by importers in terms of higher prices, and in this case the constraint in the number of links will come from the importing country.

3 We use bilateral import data for each of the 222 countries to connect the origin and the destination of a trade flow rather than export data, as imports are generally believed to be more reliable and complete, being recorded for most countries at the customs level to collect tariffs and other duties, for security reasons, and so on. Given the size of our dataset, the maximum potential number of arcs for each industr is

of 259,263 disaggregated bilateral flows, representing an average of 9259 flows per sector and 1168 flows per country. These average figures hide large differences between countries and between sectors, which give rise to distinctive network structures.

### 3.1 Characteristics of the trade networks

The main characteristics of a network can be summarized by some indices that we computed for all the sectors in our dataset, reported in Table 1. By including all 222 countries in all the 28 sectoral networks, we have networks with the same size in terms of vertices, but with a quite different number of arcs. A country (a vertex of the network) can be both a sender and a receiver of arcs, i.e., an exporter and an importer in each industry. The *degree* of a vertex (defined as the number of arcs connecting the vertex to the network) is in this case the number of trading partners of a country, and import flows from each partner can be counted as the *indegree,* while the *outdegree* is the number of export flows. The average degree of a network is computed simply as the total number of arcs divided by the number of vertices, and it is by definition the same considering indegrees or outdegrees. This is why only one average degree is reported in Table 1 for each sector. In our sample, the mean across sectors of the average degree is equal to 42, but there are remarkable differences from sector to sector, going from 12.11 to 64.43 (see Table 1, column [3]).

The cumulative distribution of the indegrees and outdegrees for each sector is reported in the Appendix. We observe that the outdegrees are never normally distributed, while the indegrees are normally distributed in a few sectors. In general, there are relatively more countries with a smaller number of outgoing links than expected in a normal distribution. In other words, exporting countries in a given industry tend to have a relatively low number of export markets. Given the non-normal distribution of degrees, it is also informative to look at the median of the indegrees and outdegrees, which can instead be different. Indeed, in all sectors the median indegree is much higher than the median outdegree (Table 1, columns [4] and [6]). This confirms what can be observed in the cumulative distribution functions, where the indegrees tend to increase faster than the outdegrees. This finding at the sectoral level is in line with a similar observation for the aggregated

222 * 221 = 49062, i.e., if every country would trade with every other country, in every industry we would observe 49062 trade flows.

world trade network (see De Benedictis and Tajoli 2009): export markets are generally more limited in number than import sources, suggesting the existence of costs to reach and penetrate new foreign markets, while import sources are more highly diversified, in line with the idea of promoting competition from import sources. The different distribution of indegrees and outdegrees is remarkable in nearly all sectors.

The average degree of a network can be used to measure the cohesion of a network. Directly related to this measure is the *density* of a network, expressed as the proportion of the number of arcs in a simple network over the maximum possible number of arcs, $\delta = m / m_{max}$, where $m_{max}$ is the number of arcs in a complete network with the same number of vertices. Accordingly, a complete network, in which every vertex is connected to every other vertex, is a network with maximum density equal to 1. Looking at the density measure in Table 1, column (2), we see that in all sectors the trade network is far from being complete, reaching at most 0.29. For comparison, Table 1 shows also the network indices computed for aggregate trade flows. Even at the aggregate level, the world trade network is largely incomplete, with a density of about 0.44. Unsurprisingly at the sectoral level, the density is much lower, being on average just about 0.19. This means that in a given industry, on average there is a probability of 19\% that two countries i and j are linked. Clearly, countries do not import from every possible source and export to every possible market, but they select their trading partners.

The position of every vertex in a network is measured in terms of *centrality,* which indicates how closely linked is a vertex to all the other vertices (see Freeman 1979). The centrality of a vertex can be interpreted as a measure of 'importance' with respect to the network structure. In the trade context, centrality measures can be computed to indicate how closely tied is a country or a group of countries to the world market.

Many distinctive measures of centrality exist, which capture different aspects of the role of a vertex within the network. The simplest measure of centrality for a vertex is the number of its neighbors, i.e. its degree. The standardized *degree centrality* of a vertex is its degree divided by the maximum possible degree, $C^d_i = d / (n-1)$. From the vertex measure of centrality is possible to define also the extent to which a network is centralized. The *degree centralization* of a network is defined relatively to the maximum attainable centralization. The minimum degree for any component of the network is 0 and the maximum possible degree is $n-1$. If $C^d_i{}^*$ is the centrality of the vertex that attains the maximum centrality score, the variation in the de-

gree of vertices is the summed absolute differences between the centrality scores of the vertices and the maximum centrality score among them. So, as the maximum attainable centrality is $(n-2)(n-1)$, the degree centralization of a network is $C^d = \Sigma_i | C^d_i C^d_i * | / ((n-2)(n-1))$, and the higher the variation in the degree of vertices, the higher the centralization of a network. In directed networks, degree centralization can be measured both in terms of indegrees and outdegrees. The centralization of a network is an important indicator of the organization of the network, with a low centralization indicating that all vertices are in similar positions with respect to each other, while a high centralization indicates that the structure of the network is built around some special vertices.[4]

Degree centralization is associated to direct links, but when connections in a network acquire some relevance, one should give prominence also to indirect links. This brings us to the concept of *distance* in networks, namely the number of steps needed to connect two vertices. The shorter the distance between two vertices, the closer is the connection between them. The *geodesic distance* is the shortest path between two vertices.

The notion of geodesic distance is at the bulk of another definition of centrality, based on the intuition that a vertex is central if it is essential in the indirect link between other vertices. A vertex that is located on the geodesic distance between many pairs of vertices plays a central role in the network, and in a pure star, the core is central because it is necessary for all periphery vertices in order to be mutually reachable. This concept of centrality is based on betweenness, so it is called *betweenness centrality*. The betweenness centrality of a vertex can be loosely defined as the number of times that a node lies along the shortest path between two others.[5] The *betweenness centralization* of a network is the variation in the betweenness centrality of vertices divided by the maximum variation in betweenness centrality scores possible in a network of the same size. The notion of betweenness centrality has important strategic implications. The central vertex could, in fact, exploit its position to its advantage.

4 The centralization of a pure star (i.e. a network with one central vertex connected to all the others, while all other vertices are connected only to the center and not to each other) is 1. The centralization of a regular network (i.e. a network where all vertices have the same degree) is 0.

5 More formally, it is the proportion of all geodesic distances between pairs of other vertices that include this vertex (Vega-Redondo, 2007). The core of a star network has maximum betweenness centrality, because all geodesic distances between pairs of other vertices include the core. In contrast, all other vertices have minimum betweenness centrality, because they are not located between other vertices.

**Table 1:** Trade networks characteristics in the year 2000

| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ISIC code** | **Industry** | **% on tot. trade value** | **Arcs** | **Density** | **Average degree** | **Indegree Median** | **Indegree st.dev.** | **Outdegree Median** | **Outdegree st.dev.** | **Indegree central.** | **Outdegree central.** | **Betweeness central.** | **Countries in core** |
| 311 | Food products | 4.5 | 12710 | 0.2591 | 57.25 | 54.50 | 35.96 | 32.00 | 56.21 | 0.4852 | 0.6443 | 0.0488 | 72 |
| 313 | Beverages | 0.7 | 7078 | 0.1443 | 31.88 | 28.50 | 23.69 | 14.00 | 43.36 | 0.4323 | 0.7051 | 0.0755 | 41 |
| 314 | Tobacco | 0.3 | 3651 | 0.0744 | 16.45 | 14.00 | 13.98 | 4.00 | 28.99 | 0.2662 | 0.6116 | 0.1031 | 28 |
| 321 | Textiles | 3.5 | 12829 | 0.2615 | 57.79 | 54.50 | 38.45 | 40.00 | 55.18 | 0.5100 | 0.6191 | 0.0459 | 74 |
| 322 | Apparel | 3.9 | 11475 | 0.2339 | 51.69 | 44.00 | 38.75 | 32.50 | 51.42 | 0.5605 | 0.6605 | 0.0618 | 65 |
| 323 | Leather products | 0.7 | 7842 | 0.1598 | 35.32 | 28.00 | 29.95 | 16.50 | 43.93 | 0.4531 | 0.6440 | 0.0611 | 58 |
| 324 | Footwear | 0.7 | 6623 | 0.1350 | 29.83 | 25.00 | 24.58 | 9.00 | 41.11 | 0.4371 | 0.6326 | 0.1040 | 47 |
| 331 | Wood products | 1.1 | 8884 | 0.1811 | 40.02 | 31.50 | 33.48 | 22.00 | 43.94 | 0.5272 | 0.6408 | 0.0705 | 58 |
| 332 | Furniture | 1.0 | 8522 | 0.1737 | 38.39 | 36.00 | 28.82 | 19.00 | 47.07 | 0.5073 | 0.6846 | 0.0993 | 57 |
| 341 | Paper products | 2.5 | 8984 | 0.1831 | 40.47 | 39.50 | 27.02 | 15.00 | 50.59 | 0.4070 | 0.6660 | 0.0779 | 54 |
| 342 | Printing and publishing | 0.7 | 9585 | 0.1954 | 43.18 | 41.00 | 30.83 | 21.00 | 50.22 | 0.4719 | 0.6946 | 0.0640 | 55 |
| 351 | Industrial chemicals | 7.9 | 11627 | 0.2370 | 52.37 | 51.00 | 34.06 | 27.00 | 55.70 | 0.4392 | 0.6619 | 0.0542 | 65 |
| 352 | Other chemicals | 4.1 | 11748 | 0.2395 | 52.92 | 55.50 | 30.92 | 26.00 | 57.66 | 0.4367 | 0.6685 | 0.0477 | 57 |
| 353 | Petroleum refineries | 2.8 | 5338 | 0.1088 | 24.05 | 20.00 | 18.60 | 7.00 | 37.26 | 0.3407 | 0.6271 | 0.1088 | 38 |
| 354 | Petroleum and coal prod. | 0.1 | 2689 | 0.0548 | 12.11 | 8.50 | 11.34 | 1.00 | 25.69 | 0.1859 | 0.5586 | 0.0689 | 30 |
| 355 | Rubber products | 0.9 | 8951 | 0.1824 | 40.32 | 42.00 | 25.79 | 11.00 | 53.32 | 0.3849 | 0.6758 | 0.0778 | 60 |
| 356 | Plastic products | 1.2 | 10286 | 0.2097 | 46.33 | 46.00 | 29.58 | 21.00 | 54.02 | 0.3985 | 0.6621 | 0.0598 | 64 |
| 361 | Pottery, china, earthenware | 0.2 | 6604 | 0.1346 | 29.75 | 25.50 | 24.89 | 10.50 | 41.37 | 0.4193 | 0.6466 | 0.0813 | 58 |
| 362 | Glass products | 0.5 | 7979 | 0.1626 | 35.94 | 35.00 | 24.75 | 10.00 | 49.28 | 0.3639 | 0.6775 | 0.0604 | 57 |
| 369 | Other non-metal mineral pr. | 0.6 | 7846 | 0.1599 | 35.34 | 33.00 | 24.18 | 11.00 | 47.74 | 0.3666 | 0.6893 | 0.0663 | 47 |
| 371 | Iron and steel | 2.9 | 8465 | 0.1725 | 38.13 | 34.00 | 26.24 | 14.50 | 49.63 | 0.3585 | 0.6676 | 0.0550 | 49 |
| 372 | Non-ferrous metals | 2.8 | 7619 | 0.1553 | 34.32 | 26.00 | 29.88 | 15.00 | 41.75 | 0.4485 | 0.6622 | 0.0937 | 56 |
| 381 | Fabricated metal products | 2.9 | 12195 | 0.2486 | 54.93 | 54.00 | 34.55 | 30.50 | 57.56 | 0.4958 | 0.6548 | 0.0481 | 59 |
| 382 | Machinery, except electric | 16.7 | 14304 | 0.2915 | 64.43 | 60.00 | 40.51 | 41.00 | 59.54 | 0.5435 | 0.6298 | 0.0437 | 63 |
| 383 | Machinery, electric | 17.1 | 13055 | 0.2661 | 58.81 | 56.50 | 39.18 | 33.50 | 57.71 | 0.5781 | 0.6463 | 0.0464 | 63 |
| 384 | Transport equipment | 14.9 | 11423 | 0.2328 | 51.45 | 51.00 | 33.26 | 30.00 | 54.60 | 0.5116 | 0.6797 | 0.0498 | 64 |
| 385 | Prof. and scient. equip. | 3.0 | 10430 | 0.2126 | 46.98 | 42.00 | 33.67 | 20.00 | 54.59 | 0.5501 | 0.6910 | 0.0660 | 56 |
| 390 | Other manufact. products | 1.8 | 10521 | 0.2144 | 47.39 | 44.50 | 34.32 | 24.50 | 52.84 | 0.5209 | 0.6664 | 0.0705 | 64 |
| | Aggregate bilateral trade | | 21700 | 0.4423 | 97.75 | 101.50 | 53.40 | 88.50 | 59.54 | 0.4784 | 0.5011 | 0.0147 | 104 |

*Source:* Our elaboration on BACI dataset, based on UN Comtrade.

From the centralization indices reported in Table 1, we see that all sectoral networks are quite centralized in terms of outdegree (column (9)). This measure of centralization ranges from a minimum of 0.56 to a maximum of 0.70, while at the aggregate level, the outdegree centralization of the world trade network reaches just about 0.50.[6] Betweeness centralization at the industry level is also higher than at the aggregate level (column (10)). This means that in general, export flows tend to be organized around some important countries (producers), that play a key role in the network structure. The extent of centralization is somewhat lower if we consider the indegrees. In this case, the range of the index goes from 0.18 to 0.57, and, for every industry, indegree centralization is lower than the corresponding outdegree measure. This is true also at the aggregate level, but the difference is much smaller. Considering disaggregated import flows, there seems to be only a few cases in which a limited number of central markets play a key role in the network structure.

One way to assess the distinctive position of vertices in a network is to identify the *core* of the network, if it exists.[7] A core is a relatively dense sub-network within the network, identified by a cluster of vertices with a high degree that are tightly connected to each other.[8] In our analysis, we can see the core of the network as the core of the market in a given industry, or in other words, the sub-group of countries that, having a large number of links, tend to be the market-makers. Table 1, column (11) reports the number of countries identified as belonging to the core in each industry. To identify the core, indegrees and outdegrees of all countries were considered together. In other words, the core is made both by strongly linked exporters and importers. On average, about one fourth of all countries considered belong to the core, even if also in this case there are differences between industries. The network formed by this subgroup of tightly connected countries always displays a density of 0.90 or higher.

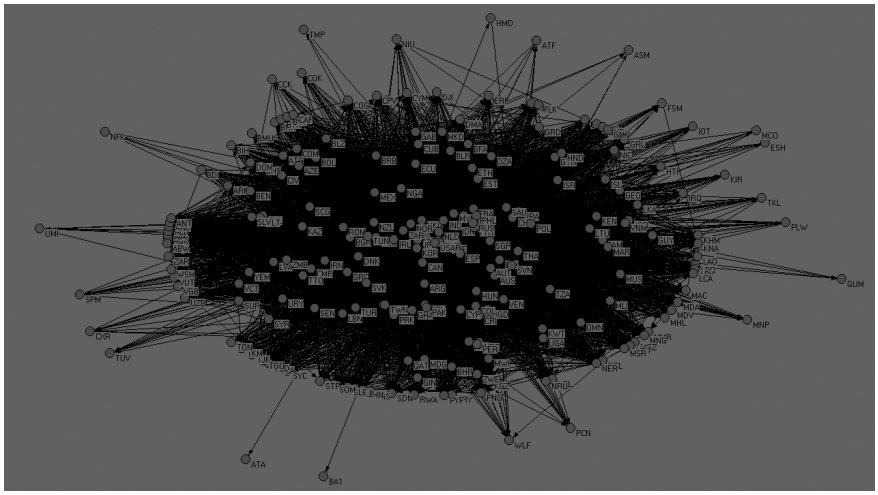
6 See also De Benedictis and Tajoli (2009) for a comparison with the world trade network indicators at the aggregate level. See also Serrano, Boguña and Vespignani (2007) for a description of the key arcs and key nodes existing in the world trade network.

7 In star networks there are two types of vertices: the core vertex is heavily linked to all vertices in the periphery, while vertices in the periphery are linked only to the core vertex. The two types have very different degrees: the degree of the unique core vertex is n–1, and the degree of the n-1 periphery vertices is 1. In regular networks, the core coincides with the entire network, so it is not possible to divide vertices between a core and a periphery.

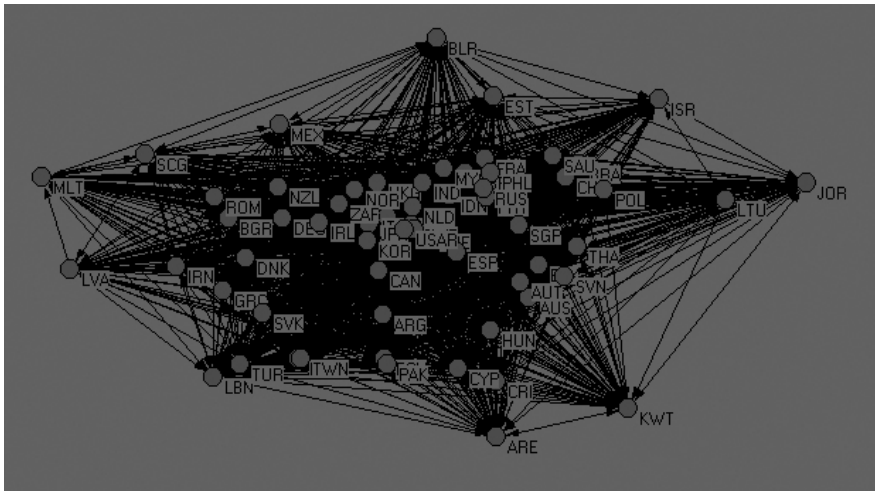
8 A k-core is identified by considering the vertices in a cluster (a group of vertices all connected to each other) that have a minimum degree k within the cluster. We assign to the core of the network the group of countries belonging to the cluster with the higher minimum degree.

The difference between trade networks in distinctive industries can be appreciated also visually. Figure 1 shows the trade network of the machinery industry and of the fuel products industries, which are the most dense and less dense networks, respectively.

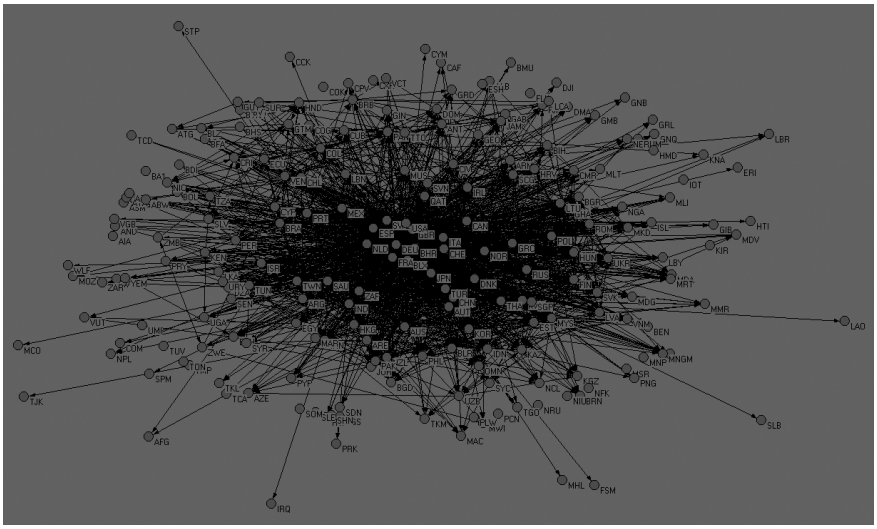
**Figure 1:** The most dense and least dense International trade networks and their core



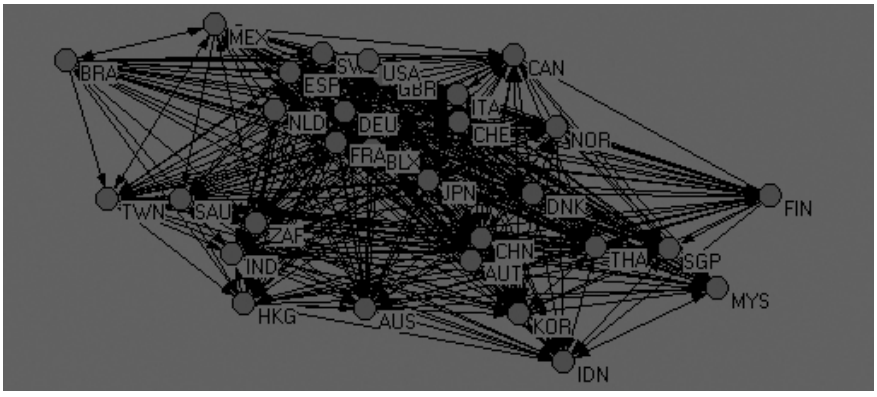

(a) Trade network for machinery (382)




(b) Core of the machinery trade network




(c) Trade network for fuel products (354)




(d) Core of the fuels trade network

## 3.2 Trade networks and goods' complexity

As mentioned, the trade networks formed by trade links in distinctive industries display quite different characteristics. We can see industries with a relatively high network density, such as machinery, both electric and non-electric (see the top panel of Figure 1), and industries with a much lower density, such as tobacco or petroleum and coal products (bottom panel of Figure 1). While machinery is a highly differentiated industry, the fuel prod-

ucts industry is based on relatively homogenous raw materials. There are industries with a more similar distribution of indegrees and outdegrees, and there are industries where the patterns of inward and outward linkages are very different (see the figures in the Appendix).

Is there a regularity in the observed networks' characteristics? Are these characteristics related to the type of goods traded and to the specific features of demand and supply for those goods? We expect this to be the case, given that economic networks, differently from random networks, arise because of the effects of cooperative forces or competitive forces at work between units of the network, which influence the network structure (see VEGA-REDONDO 2007). A random distribution of linkages between countries and a random structure is therefore very unlikely. In particular, we want to assess whether the network structure is associated to the extent of differentiation and complexity of the goods, assuming as discussed in Sect. 2 that differentiation is important in determining the potential number of transactions and the extent of the market.

Measuring differentiation in a group of products is not an obvious task. Here we follow the approach introduced by RAUCH (1999) and further developed by NUNN (2007). In the work by RAUCH, goods are classified in three groups: those traded on organized exchanges, those not traded on organized exchanges but having a 'reference price', and all other commodities. Homogeneous and differentiated goods are distinguished according to the existence of a reference price. If such a price exists (as in the first two groups), the good is classified as homogeneous, as it can be priced without seeing the good itself and checking its characteristics. If such a price does not exist, the good is classified as differentiated. Moving from this distinction, NUNN (2007) assigns to goods an index of 'complexity' or contract-intensity, which measures the fraction of differentiated intermediate inputs used to produce the good, the higher the intensity of differentiated inputs used in production, the higher the complexity of the good.[9]

We use NUNN's indicator of complexity to rank the 28 industries in our sample.[10] This indicator is presented in Table 2, with industries ranked in terms of increasing complexity.

9 Other authors try to measure the complexity of different goods. See for example LEVCHENKO (2007), who considers the number of intermediate inputs in his ranking.

10 Both RAUCH (1999) and NUNN (2007) use two classifications, defined "liberal" and "conservative", to assign products to different groups. The two classifications are highly correlated, but here we used Nunn's liberal classification and the index represents the fraction of differentiated goods, according to this liberal classification, over total inputs value.

**Table 2:** Index of complexity: fraction of differentiated inputs over total inputs in production

| ISIC code | Industry | Index of complexity |
|---|---|---|
| 353 | Petroleum refineries | 0.0577 |
| 372 | Non-ferrous metals | 0.1604 |
| 351 | Industrial chemicals | 0.2403 |
| 371 | Iron and steel | 0.2422 |
| 314 | Tobacco | 0.3166 |
| 361 | Pottery, china, earthenware | 0.3288 |
| 311 | Food products | 0.3306 |
| 341 | Paper and products | 0.3481 |
| 321 | Textiles | 0.3761 |
| 369 | Other non-metallic min. prod. | 0.3766 |
| 354 | Petroleum and coal prod. | 0.3952 |
| 355 | Rubber products | 0.4073 |
| 356 | Plastic products | 0.4077 |
| 381 | Fabricated metal products | 0.4347 |
| 352 | Other chemicals | 0.4897 |
| 331 | Wood prod., excep. furniture | 0.5162 |
| 390 | Other manufactured products | 0.5468 |
| 362 | Glass and products | 0.5574 |
| 332 | Furniture | 0.5677 |
| 323 | Leather products | 0.5706 |
| 324 | Footwear | 0.6504 |
| 342 | Printing and publishing | 0.7128 |
| 313 | Beverages | 0.7129 |
| 383 | Machinery, electric | 0.7400 |
| 322 | Apparel | 0.7454 |
| 382 | Machinery, except electrical | 0.7636 |
| 385 | Professional and scient. equip. | 0.7847 |
| 384 | Transport equipment | 0.8587 |

*Source:* NUNN (2007).

According to RAUCH (1999), search costs should act as a barrier to trade for differentiated products. Therefore, if these costs are relevant, we should not see a large number of trade links for industries with a high value of the complexity index, i.e., using a large fraction of differentiated inputs. On the other hand, the need to diversify inputs to obtain the one which is most appropriate for a specific variety of the final product, and the production of a large number of varieties of the goods can produce a large number of trade links. We then test whether goods' complexity is associated with the characteristics of the trade network, and in particular its complexity. Table 3 pre-

sents the correlations between NUNN's complexity index and the networks' characteristics.

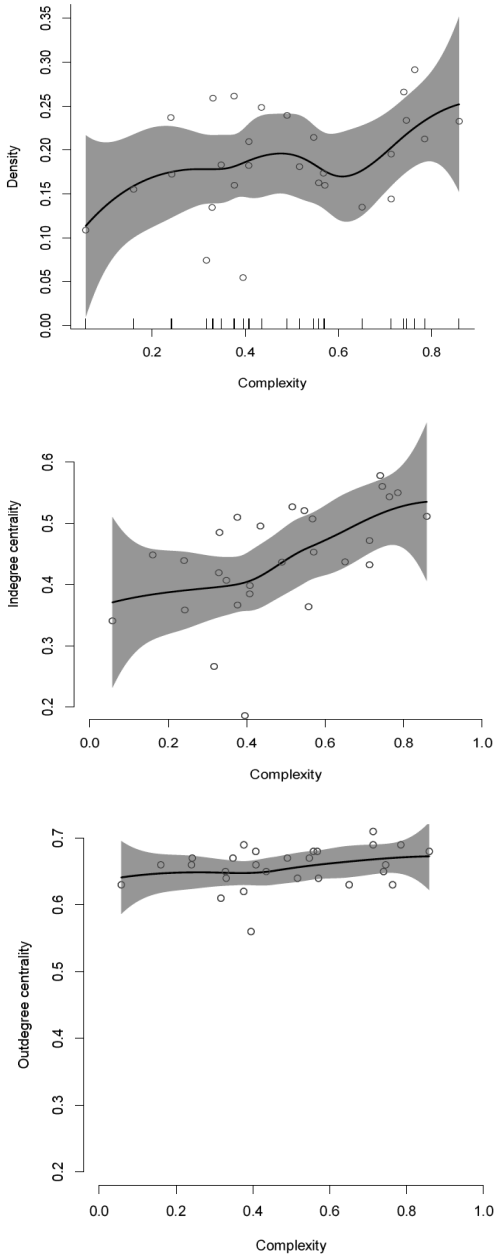
**Table 3:** Correlation between complexity and network indicators

| | Index of complex. | Density | Indegree Median | Indegree st.dev | Outdegree Median | Outdegree st.dev. | Indegree Central. | Outdegree Central. | Betweeness Central. | Countries in core |
|---|---|---|---|---|---|---|---|---|---|---|
| Complexity | 1 | 0.3738 | 0.3464 | 0.4257 | 0.3905 | 0.34 | 0.5708 | 0.3134 | -0.3303 | 0.2363 |
| Density | 0.3738 | 1 | 0.9807 | 0.9427 | 0.9470 | 0.9493 | 0.7978 | 0.3094 | -0.7507 | 0.8639 |
| Indegr. Med. | 0.3464 | 0.9807 | 1 | 0.8676 | 0.8972 | 0.9661 | 0.7083 | 0.3385 | -0.7551 | 0.8275 |
| Indegr. s.d. | 0.4257 | 0.9427 | 0.8676 | 1 | 0.9340 | 0.8526 | 0.9204 | 0.3034 | -0.641 | 0.8897 |
| Outdegr. Med. | 0.3905 | 0.9470 | 0.8972 | 0.934 | 1 | 0.8076 | 0.8066 | 0.1233 | -0.7187 | 0.8081 |
| Outdegr. s.d. | 0.3400 | 0.9493 | 0.9661 | 0.8526 | 0.8076 | 1 | 0.7156 | 0.5074 | -0.7116 | 0.8328 |
| Indegr.Centr. | 0.5708 | 0.7978 | 0.7083 | 0.9204 | 0.8066 | 0.7156 | 1 | 0.4059 | -0.391 | 0.7586 |
| Outdegr. Centr. | 0.3134 | 0.3094 | 0.3385 | 0.3034 | 0.1233 | 0.5074 | 0.4059 | 1 | -0.0982 | 0.3007 |
| Between. Centr. | -0.3303 | -0.7507 | -0.7551 | -0.6410 | -0.7187 | -0.7116 | -0.3910 | -0.0982 | 1 | -0.6089 |
| Core countries | 0.2363 | 0.8639 | 0.8275 | 0.8897 | 0.8081 | 0.8328 | 0.7586 | 0.3007 | -0.6089 | 1 |

*Source:* Our elaborations on BACI data for the year 2000.

From Table 3, we see that goods' complexity is positively correlated with the network density. The simple correlation coefficient is not very high, probably because of the non-linearity of the relationship between complexity and density. This non-linear correlation can be better appreciated looking at the relation in Figure 2. This non-linear pattern seems to indicate that as the complexity of the goods produced in a given industry increases, the number of links in the network initially increases, as the number of countries exporting the goods and importing the goods rises. But eventually, as complexity increases even further, and differentiation requires an even higher level of specialization, the number of countries trading these goods declines to some extent.

**Figure 2:** Relation between goods' complexity index and network indices




*Source:* Our elaborations.

The index of complexity displays a relatively high correlation with the measure of indegree centralization and with the standard deviation of the indegree distribution. Both these measures capture some characteristics of the indegree distribution. Goods' complexity appears associated with an uneven distribution of markets' prominence. Imports of complex goods are less homogeneously distributed across countries than simpler goods. This result is in line with the positive but very low correlation between complexity and the size of the core sub-group of countries. Considering the indegree centralization index, the positive and significant correlation with the goods' complexity seems to indicate that for highly complex goods, an important role is played by some central and well-connected markets where these goods are imported. On the contrary, outdegree centralization is always quite high, but it is seems to be very weakly related to the goods' complexity. A possible interpretation of this result is that comparative advantages tend to reduce the number of exporters in a given industry, but this concentration occurs both for more and less complex types of goods.

The only negative correlations appear for the betweeness centralization measure. It is evident that the centralization measures capture distinctive network characteristics. The higher betweeness centralization measure for less complex and less differentiated goods (often based on the use of raw materials) suggests a different structure of links. These are goods that display fewer bi-directional links, giving rise to stronger betweeness centralization.

If we look at the countries with the highest centralization indices, we can observe that in terms of indegree, the largest industrialized countries rank in the top positions in every sector (see Table 4). Market size in terms of GDP and GDP per capita unsurprisingly allow these countries to play a key role as importers. The picture changes when considering the outdegree centralization. In quite a few sectors, the highest outdegree centralization indices are found for some smaller countries and for emerging Asian economies. This indicates that the level of GDP can be a poor proxy of the role of a country as an exporter in the trade network. In the sectors where a country holds a comparative advantage, the country can play a key role in the trade network independently from its size or level of development.

**Table 4:** Countries with the highest centrality indices

| Highest indegree vertex centrality | | |
|---|---|---|
| Country | No. of times in top three positions in 28 sectoral networks | No. of times in first position |
| France | 26 | 13 |
| USA | 24 | 10 |
| Germany | 19 | 3 |
| UK | 10 | 1 |
| Italy | 5 | 1 |
| **Highest outdegree vertex centrality** | | |
| Country | No. of times in top three positions in 28 sectoral networks | No. of times in first position |
| Germany | 24 | 9 |
| UK | 19 | 7 |
| USA | 14 | 2 |
| Italy | 7 | 2 |
| Japan | 5 | 2 |
| Indonesia | 4 | 3 |
| Thailand | 4 | 2 |
| France | 4 | 1 |
| Netherlands | 2 | 0 |
| Spain | 1 | 0 |

*Source:* Our elaborations on BACI data.

## 4 Conclusion

Using the tools of network analysis, in this paper we examined some of the characteristics of the structure of trade flows in different industries. Through the indices describing the network's properties, such as density, degree distribution and centrality, we show that trade networks display remarkable differences.

In particular, the analysis of trade networks seems to confirm our initial hypothesis that homogenous and less complex goods give rise to less dense trade networks. This means that international competition in the world markets is not necessarily stronger in industries producing more homogenous goods.

Our results also show that generally more complex goods are associated with more complex networks. The relationship appears to be positive, but not linear. Therefore, for complex and differentiated goods, the forces pushing countries to create more trade links tend to prevail, even if also for differentiated goods the trade network is far from being complete, as trade costs play a significant role.

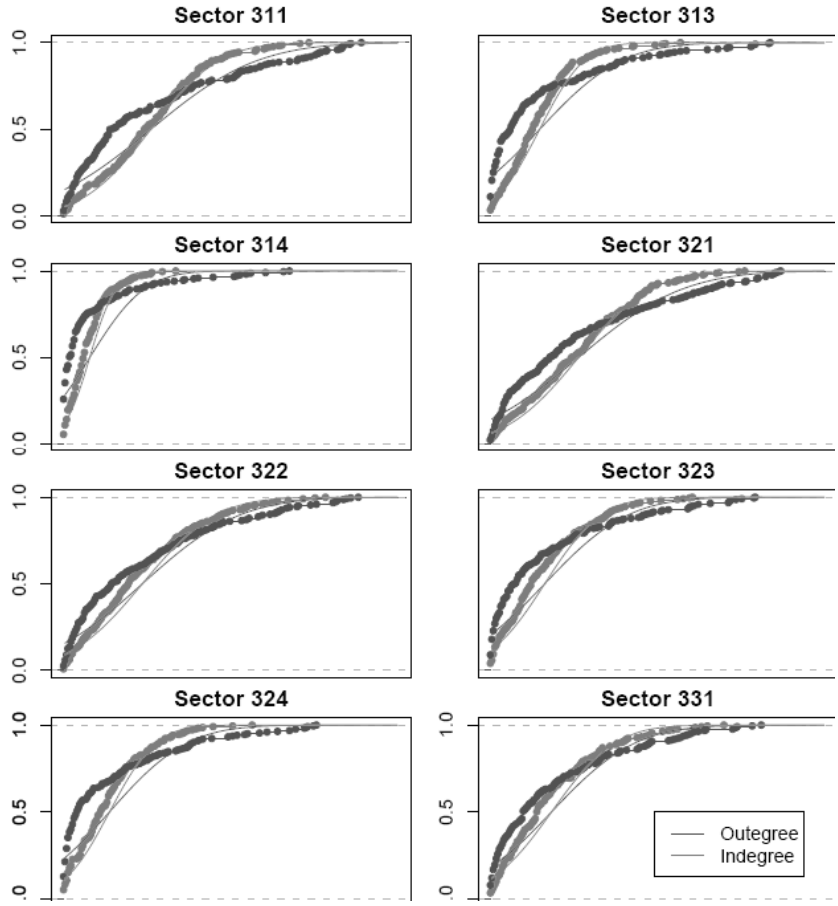
We can also see that the trade of complex goods is not restricted to a very small number of countries, but instead as complexity increases, the number of countries involved in trade tends to increase. This result is in line with the idea that higher complexity and higher specialization go together with a finer international division of labor, that involves an increasing number of countries.

Finally, the strong correlation between goods' complexity and the centralization of the indegrees hints to the important role that importing markets play in shaping the trade flows of the most complex goods. At the industry level, for all goods we observe an uneven distribution of production, arguably related to the different comparative advantage of countries. Instead, the distribution of demand is remarkably different across industries, and it seems to be especially skewed for the most complex goods.

## Appendix

Cumulative distribution functions of indegrees and outdegrees in the observed industries

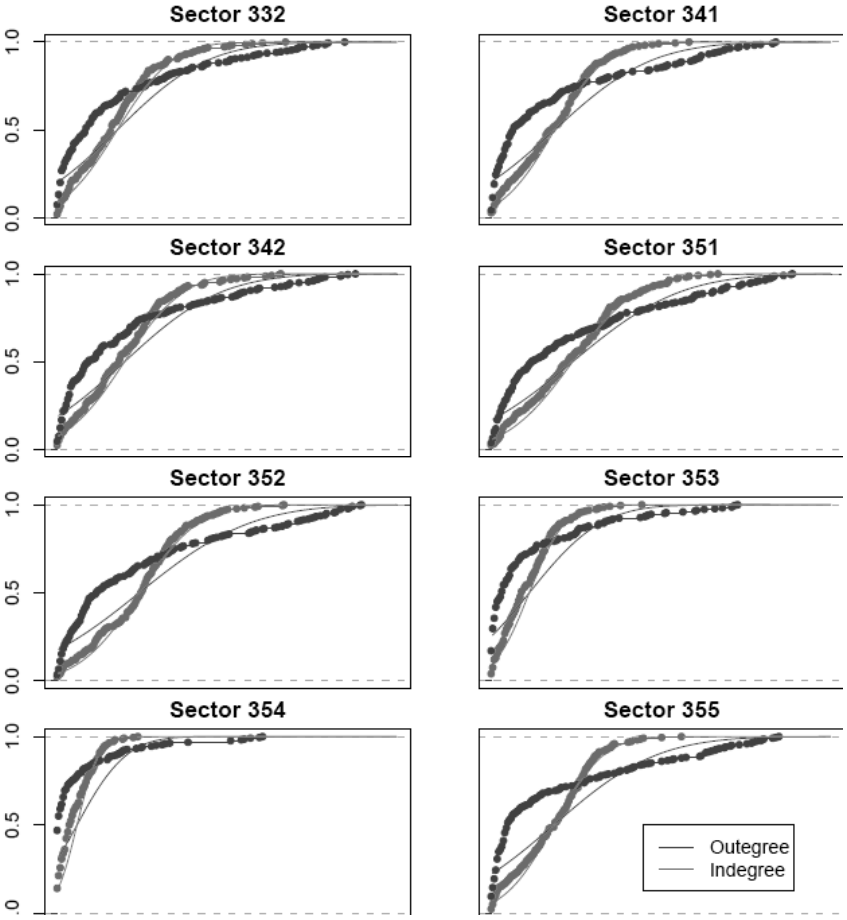
**Figure 3 (a)**




Note: actual cumulative distribution functions of indegrees and outdegrees are represented by the dots, while continuous lines are the normal distrubutions.

*Source:* Our elaborations.

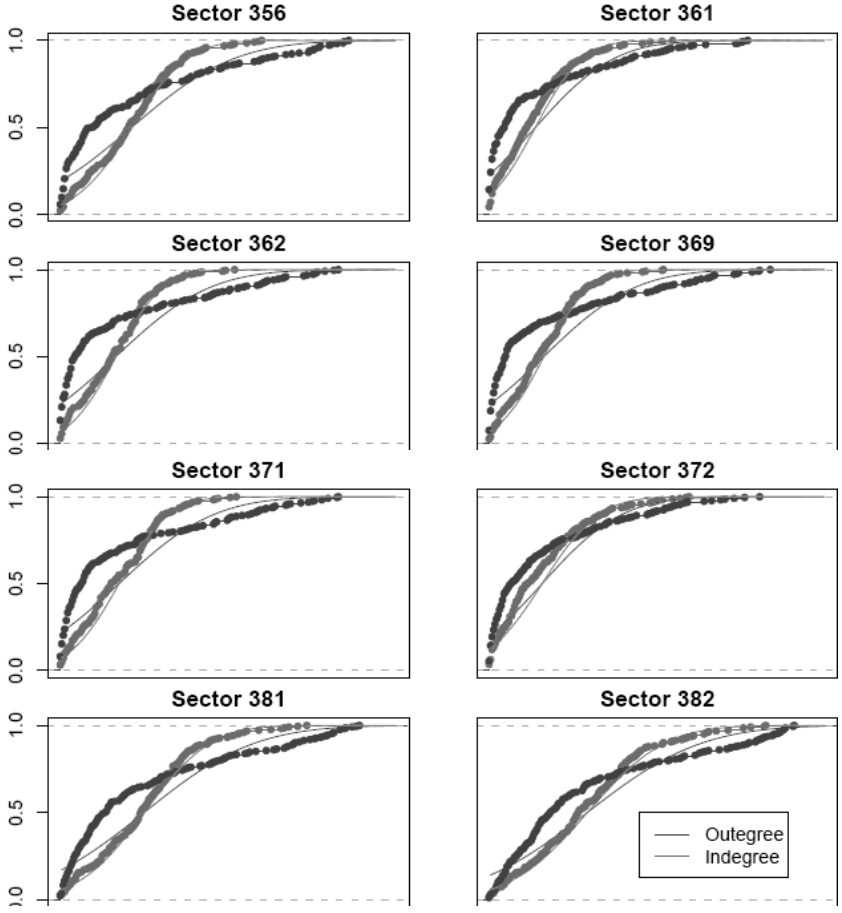
**Figure 3 (b)**




Note: actual cumulative distribution functions of indegrees and outdegrees are represented by the dots, while continuous lines are the normal distrubutions.

*Source:* Our elaborations.

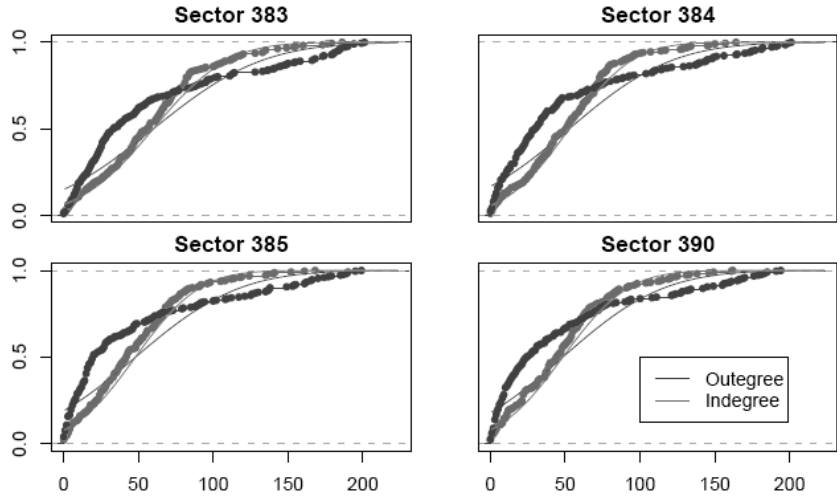
**Figure 3 (c)**




Note: actual cumulative distribution functions of indegrees and outdegrees are represented by the dots, while continuous lines are the normal distrubutions.

*Source:* Our elaborations.

**Figure 3 (d)**




Note: actual cumulative distribution functions of indegrees and outdegrees are represented by the dots, while continuous lines are the normal distrubutions.

*Source:* Our elaborations.

## References


ANDERSON, JAMES E. and ERIC VAN WINCOOP (2003), Gravity with Gravitas: A Solution to the Border Puzzle, *American Economic Review* 93 (1), pp. 170–192.

DE BENEDICTIS, LUCA and LUCIA TAJOLI (2008), *La rete degli scambi mondiali,* L'Italia nell'economia internazionale, Rapporto ICE 2007–2008, Istituto Nazionale per il Commercio Estero, Roma.

DE BENEDICTIS, LUCA and LUCIA TAJOLI (2009), The World Trade Network, *FREIT Working Paper* No. 121.

DE NOOY, WOUTER, ANDREJ MRVAR and VLADIMIR BATAGELJ (2005), *Exploratory Social Network Analysis with Pajek,* New York: Cambridge University Press.

DIXIT, AVINASH K. and VICTOR D. NORMAN (1980), *Theory of International Trade,* New York: Cambridge University Press.

FREEMAN, LINTON C. (1979), Centrality in social networks: conceptual clarifications, *Social Networks* 23 (1), pp. 215–239.

GAULIER, GUILLAUME and SOLEDAD ZIGNAGO (2008), BACI: A World Database of International Trade at the Product-level, *CEPII Working Paper* No. 2008 (3), July.

GOYAL, SANJEEV (2007), *Connections, An Introduction to the Economics of Networks,* Princeton: Princeton University Press.

HELPMAN, ELHANAN, MARC MELITZ and YONA RUBINSTEIN (2008), Estimating Trade Flows: Trading Partners and Trading Volumes, *Quarterly Journal of Economics* 123 (2), pp. 441–487.

JACKSON, MATTHEW O. (2005), *The Economics od Social Networks,* in: BLUNDELL R., W. NEWEY and T. PERSSON, *Proceedings of the 9th World Congress of the Econometric Society,* New York: Cambridge University Press.

KRUGMAN, PAUL R. (1980), Scale Economies, Product Differentiation, and the Pattern of Trade, *American Economic Review,* 70 (5), pp. 950–959.

LEVCHENKO, ANDREI (2007), Institutional Quality and International Trade, *Review of Economic Studies* 74 (3), pp. 791–819.

NUNN, NATHAN (2007), Relationship-Specificity, Incomplete Contracts, and the Pattern of Trade, *Quarterly Journal of Economics* 122.

RAUCH, JAMES E. (1999), Networks vs. markets in international trade, *Journal of International Economics* 48, pp. 7–37.

SERRANO M. ÁNGELES, MARIAN BOGUÑA and ALESSANDROVESPIGNANI (2007), Patterns of dominant flows in the world trade web, *Journal of Economic Interaction and Coordination* 2, pp. 111–124.

VEGA REDONDO FERNANDO (2007), *Complex Social Networks,* New York: Cambridge University Press.

Anteile der weltweiten Konjunkturprogramme und zeigen, dass das UN-Ziel in fast allen Ländern deutlich verfehlt wurde. Außerdem bewerten wir die unterschiedlichen «grünen» Maßnahmen bezüglich ihrer Stabilisierungswirkung und ihres Beitrags zum Klimaschutz. Für eine Stützung der Konjunktur und gleichzeitige Lenkung der Wirtschaft auf einen langfristig nachhaltigen Wachstumspfad bieten sich die Vorziehung von ohnehin geplanten Maßnahmen im Bereich der Gebäudesanierung, der Energieeffizienz und des Ausbaus des Energienetzes an.

Worldwide, approximately 3 trillion dollars have been earmarked by governments for stimulus packages aimed at remedying the global economic downturn provoked by the financial crisis. Calling for a "Global Green New Deal" the UN stipulated that about 25 percent of this money should be spend for emission-saving measures and structural adjustments to initiate climate friendly growth. Otherwise, the consequences of the climate crisis might exceed the consequences of the financial crisis in the near future. This study analyses the "green" share of the worldwide stimulus packages and shows that in almost all countries the UN target of 25 percent is missed. Additionally, we evaluate the various "green" measures with respect to their effect on economic growth and climate protection. In particular, bringing forward already planned measures which improve building insulation, increase energy efficiency, and extend the energy grid are identified as ideal candidates to stimulate the economy and to put it on a new sustainable long term growth path.

## Comparing Sectoral International Trade Networks
*Luca De Benedictis and Lucia Tajoli* 167

This paper uses the tools of network analysis to assess the different characteristics of world trade in different manufacturing industries. The structure of the trade network s is compared to understand to what extent the world market characteristics differ between sectors. We fin that in some sectors the structure of trade flows gives rise to a dense, widespread network with many links, while in others we observe a centered network, organized around hubs that centrally coordinate the flows. The results indicate a pattern of network structures, showing a positive correlation between the goods' complexity and the network complexity, changing the extent of the relevant market and its structure across goods.

Dieser Artikel benutzt die Netzwerkanalysetechniken um die verschiedenen Eigenschaften des Welthandels in verschiedenen Produktionsindustrien zu untersuchen. Mit dem Ziel, zu verstehen wie weit sich die Eigenschaften des Welthandels zwischen Sektoren unterscheiden, werden die Strukturen der Handelsnetzwerke verglichen. Wir zeigen, dass die Struktur der Handelsflüsse in gewissen Sektoren zu dichten, grossflächigen Netzwerken mit vielen Verbindungen führt. In anderen Sektoren finden wir zentrierte Netzwerke, welche um zentrale Knotenpunkte organisiert sind und in welchen die Flüsse

zentral koordiniert werden. Die Resultate zeigen ein Muster von Netzwerkstrukturen mit einer positiven Korrelation zwischen der Komplexität der Güter und der Komplexität der Netzwerke, verbunden auch mit einer Variation der Ausdehnung des relevanten Marktes und dessen Struktur über die verschiedenen Produkte.

Does ASEAN Freer Trade Benefit Malaysia?
*Jamal Othman and Yaghoob Jafari* 191

This paper examines the impact of intra-ASEAN trade liberalization (AFTA) using a multi-country, computable general equilibrium model (GTAP Model) with special focus on Malaysia. The study considers the full elimination of intra-ASEAN import taxes and export subsidies. Results suggest that Malaysia's GDP would only increase marginally while the effects on the individual commodity sectors in the country differ substantially. Specifically, Malaysian processed food and textiles are anticipated to expand pronouncedly following the intra-ASEAN freer trade.

Dieser Artikel untersucht den Einfluss von Handelsliberalisierungen innerhalb der ASEAN-Staaten (AFTA) unter der Verwendung eines «multi-country, computable general equilibrium» Modells mit speziellem Fokus auf Malaysia. Die Studie betrachtet die vollständige Aufhebung von Importzöllen und Exportsubventionen innerhalb der ASEAN-Staaten. Die Resultate zeigen, dass Malaysias BIP nur marginal steigen würde, die Effekte für einzelne Sektoren jedoch sehr unterschiedlich sind. Im Speziellen wird erwartet, dass die malaysischen Lebensmittel- und Textilsektoren in Folge freien Handels innerhalb der ASEAN-Staaten beträchtlich expandieren würden.

## Buchbesprechungen – Book Reviews

JANE KELSEY (2008):
Serving Whose Interests? The Political Economy Of Trade In Services Agreements
*Victoria Lietha and Shrey Kapoor* 217

AADITYA MATTOO, ROBERT M. STERN AND GIANNI ZANINI (2008):
A Handbook Of International Trade In Services
*Darya Gerasimenko* 221

## Autoren – Authors 225

**Sebastian Petrick**
Institut für Weltwirtschaft
Düsternbrooker Weg 120
D-24105 Kiel
Germany
*sebastian.petrick@ifw-kiel.de*

**Luca De Benedictis**
DIEF-University of Macerata
Via Crescimbeni 20
Macerata 62100
Italy
*debene@unimc.it*

**Lucia Tajoli**
Dipartimento di Ingegneria Gestionale
Politecnico di Milano
Piazza Leonardo da Vinci 32
Milano 20133
Italy
*lucia.tajoli@polimi.it*

**Jamal Othman**
Professor of Economics
School of Economics
Faculty of Economics and Business
Universiti Kebangsaan Malaysia
43650 Bangi
Selangor
Malaysia
*jortman@ukm.my*

**Yaghoob Jafari**
Ph.D candidate
School of Economics
Faculty of Economics and Business
Universiti Kebangsaan Malaysia
43650 Bangi
Selangor
Malaysia
*yaghoob.jafari@gmail.com*

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.