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Smart specialisation in the tangled web of European inter-regional trade

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Abstract

This work presents a new methodology to assess the outward connectivity among regional economies in the EU and derives policy lessons for the design of regional innovation and competitiveness-enhancing strategic frameworks, with particular reference to research and innovation strategies for smart specialisation (RIS3).

We study the network of inter-regional trade flows in the EU25 in the year 2007. Trade data are taken from the PBL Netherlands Environmental Assessment Agency database and mapped onto weighted directed networks in which the nodes represent regions and the links are flows of goods. We measure several structural characteristics of the networks, both global properties and centrality indicators describing the position of individual regions within the system.

European regions appear to be mostly integrated in the European single market. Strengths and weaknesses of individual regions are discussed based on rankings obtained from network centrality indicators. Specific policy implications in the context of RIS3 are derived in the case of the Spanish region of Andalusia.

We show the potential of the methodology for providing a new family of indicators of the external connectivity of regional economies that can be used by regions wishing to develop their own RIS3 for 2014-2020, as required by the EU in the context of the new cohesion policy framework.

Keywords: inter-regional trade, regional competitiveness, complex networks, centrality indicators, smart specialization.

[a] The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

1. Introduction

This paper proposes the use of network methodologies to analyse the outward dimension of regional economies in the European Union, with a special focus on trade flows. We build inter-regional trade networks of agricultural and processed-food products in the EU25 (250 NUTS2 regions), and we measure several topological characteristics, both global properties of the network and indicators describing the position of individual regions within the system. We then discuss how the network methodology and the first results we obtained are relevant for the design of Research and Innovation Strategies for Smart Specialisation (RIS3), based on the case of Andalusia.

The rationale for this paper is the need for regions to perform a sound analysis of their embeddedness in a wider network of economic linkages with other regions and countries, and their positioning within this network at the national and international levels, as a constituent of and essential tool for the development of RIS3. National or regional RIS3 are defined by the European Commission's RIS3 guide (European Commission, 2012a) as integrated, place-based economic transformation agendas that focus policy support and investments on key challenges and needs for knowledge-based development, building on national/regional strengths, competitive advantages and potential for excellence. Such strategies are to support technological as well as practice-based innovation, aimed at stimulating private sector investment while ensuring full involvement of key stakeholders, and should include rigorous monitoring and evaluation systems.

RIS3 is a strategic framework for selective R&D and innovation policy making. In order to guide public investment choices effectively, RIS3 requires a comprehensive and thorough analysis of the economic and societal context of a region or country. Assessment of outward elements and external connectivity of territorial economic systems are key components of this analytical effort.

Regions need to position themselves in European and global value chains and to improve their connections and cooperation with other regions, clusters and innovation players, as discussed extensively in Thissen *et al*. (2013a). This is important for their companies' internationalisation efforts, achievement of a critical potential of cluster activities and generation of inflows of knowledge relevant to the region's existing knowledge base.

For this reason, research and innovation strategies for smart specialisation need to take account of the external context, both national and international, and pay attention to inter-regional and international cooperation in innovation policies, an aspect that has been identified as critical for the success of the RIS3 process.

Without assessing RIS3 vis-à-vis other regions, there is a risk that the perceived potential will be challenged by external competitors, thus jeopardising support efforts. Therefore, identification of complementarities with other regions in order to establish inter-regional cooperation frameworks that will enhance these regions' ability to compete in the global economy is a key element of smart specialisation.

The availability of instruments providing the necessary analytical underpinning for the process of strategy design is a necessary precondition for defining the most appropriate strategic priorities and policy instruments. This paper focuses on the tools required for analysis and comparative assessment of regional economies and their embeddedness in inter-regional and international economic networks. This is arguably one of the most pressing challenges for the design and implementation of RIS3, and its successful resolution is a precondition for effective application of the smart specialisation logic to any given territorial context.

The paper is structured as follows. Section 2 presents the policy background and the motivation of the paper; Section 3 discusses linkages with the relevant literature; Section 4 introduces the network methodology; Section 5 describes the data; Sections 6 and 7 present the results; Section 8 discusses the policy implications for RIS3 based on the case of Andalusia; and Section 9 concludes the paper.

2. Motivation and policy background

The concept of smart specialisation has acquired great relevance in the EU policy context as a tool that can contribute to enhancing competitiveness both at the regional and aggregate EU level. The concept was originally developed in the context of the transatlantic productivity gap (Foray and Van Ark, 2007); smart specialisation was seen as a means to attract international research and development (R&D) activities to Europe by both completing the European Research Area and encouraging regions to stimulate innovation and develop distinctive areas of specialisation for the future.

The concept was further refined by the Knowledge for Growth expert group set up by the European Commission in 2005, which moved a step forward by translating an originally sector-oriented rationale into a place-based approach. In particular, the Knowledge for Growth group pointed to the importance of encouraging investment in priorities identified by combining the results of comparative analyses of actual and potential strengths and weaknesses at the national and international level, and a process of entrepreneurial discovery that reveals where entrepreneurial activity is most likely to support successful specialisation.

Smart specialisation has subsequently been at the core of the revised European cohesion policy, as a fundamental driver of a successful Europe 2020 strategy (European Commission, 2010a). The European Commission communication "Regional policy contributing to smart growth in Europe" (European Commission, 2010b) in October 2010 encouraged regions to design innovation strategies for smart specialisation. In addition, the draft overarching regulation for the new 2014-2020 cohesion framework foresees that the disbursement of structural funds under the thematic objectives most directly related to R&D, innovation, information and communication technology (ICT) development, and support to SMEs will be conditional on the existence of a national or regional RIS3 in line with the National Reform Programme and including a chapter devoted to digital growth. Thus, smart specialisation is an ex-ante condition for the deployment of structural funds in these key areas.

Finally, the European Commission has created the Smart Specialisation Platform to support regional policy makers in the process of applying the logic of smart specialisation to their specific contexts.

Hence, smart specialisation was conceived as a place-based yet outward-looking approach to innovation policy, which emphasises the importance of exploiting regional competitive advantages and sourcing a variety of related inputs and knowledge, in order to exploit the assets at the disposal of a given region to identify, through a process of entrepreneurial discovery involving all relevant actors, the most promising sectors on which to concentrate public and private resources.[1]

Although the rationale for smart specialisation has significant potential for increasing the efficiency and effectiveness of innovation policies in Europe, the concept poses several methodological difficulties and implies a significant number of challenges to policy makers in the process of developing and implementing a regional or national innovation strategy for smart specialisation.

There is broad agreement around the idea that a thorough assessment of the regional economic context underpinning the decision-making process is a key feature of smart specialisation. Foray *et al*. (2009, p. 2) describe this main role for regional policy makers in the process: "Public entities can play an important infrastructural role [in selecting the right areas for specialisation] by providing and collating appropriate information about emerging technological and commercial opportunities and constraints, product and process safety standards for domestic and export markets, and external sources of finance and distribution agencies".

McCann and Ortega-Argilés (2013, p. 10) advocate for careful analysis of the regional context: "[success of policy intervention] can only be achieved if a smart specialization regional policy logic is accompanied by a rigorous self-assessment of a region's knowledge assets, capabilities and competences".

Such information is fundamental for the performance of a sound diagnosis of the state of and prospects for smart specialisation in a region or country, and should include an assessment of existing regional assets, capacities and competitive advantages, the region's positioning in the EU and global context, the number and intensity of flows and absorption of external knowledge and skills and, finally, the region's entrepreneurial dynamics. This will enable evaluation of the existing

[1] On the importance of related variety in inputs, see Frenken *et al*. (2007) and Boschma and Gianelle (2014); on the process of entrepreneurial discovery, see Foray and Goenaga (2013) and Foray and Rainoldi (2013).

capabilities for entrepreneurial discoveries of future specialisation and involvement of entrepreneurial actors in the regional economy (European Commission, 2012a).

In particular, the paper intends to develop a technique that can serve as the basis for a methodology to measure regional external flows relevant to the outward dimension of smart specialisation, focusing on one of the main indicators of regional connectivity, namely trade flows - specifically inter-regional trade flows.

As highlighted by McCann and Ortega-Argilés (2013, p. 7): "connectivity relates to all the transactions associated with trade, transportation, passenger movements, information flows, knowledge interactions, financial flows, funds management, and international decision-making capabilities, which are situated at a particular location". The methodology builds on recent evidence-based research on place-based development and smart specialisation extending ways to analyse the importance of inter-regional networks (Thissen *et al.*, 2013a).

The importance of outward aspects for smart specialisation is clear. In order for a region to expand its markets through innovation, to stimulate economic development, to attract private investment and the attention of international investors, it is important to position and brand regional expertise in a specific knowledge sector or niche market and to provide solid, integrated support to continuously strengthen this specialisation. By focusing on what provides the region's greatest competitive potential, smart specialisation helps to position the region in specific global markets/niches and international value chains. International differentiation and technology diversification are key to (re-)positioning a region in a global, highly dynamic and changing context and to make regional strategies stand out from those of other regions.

Thus, the RIS3 process needs to take account of the positioning of the regional economic and innovation system within the EU, assessing the strategy vis-à-vis neighbour, partner and competitor regions, and also the competitive position of the country/region with regard to other countries/regions in the EU and beyond, and the focal region's positioning within global value chains.

In this paper we analyse the position and embeddedness of regions in international trade networks in order to determine their economic strength in different European markets and to identify potential competitors. This information is crucial for building an effective RIS3 that takes full account of the positioning of the region's activities.

3. Regional profiling and benchmarking methods

Regional policies aimed at promoting knowledge-driven growth and development and RIS3 in particular, should be underpinned by a thorough understanding of the regional economic structure and competitive position of the economy in the national and international context.

Regional *profiling* refers to the set of analyses that should be implemented and the associated evidence that should be collected in order to construct a source of knowledge to inform strategic choices and actions. The definition and use of profiling techniques is the first stage in the design and implementation of RIS3 strategies, and has substantial implications for the further development of the subsequent stages (European Commission, 2012a).

For a profiling exercise to be meaningful and truly informative, it is crucial systematically to compare different aspects, dimensions and performance of the regional economy with those of other regions to act as a reference. Thus, activities that are grouped under the umbrella of regional profiling cannot be separated from those referred to as regional benchmarking. The SWOT analysis at the basis of RIS3 can be considered a comprehensive profiling exercise carried out in an inter-regional, internationally comparative way.

There are several examples of profiling techniques and several international institutions and organisations have well-developed methodologies and data repositories for profiling and benchmarking national/regional economies. We discuss some of the main experiences in this field, although this discussion is not exhaustive. The European Commission currently has in place a number of initiatives, such as the Innovation Union Scoreboard (European Commission, 2013), the Regional Innovation Scoreboard (European Commission, 2012b) and the Regional Innovation Monitor (Walendowski *et al*., 2010). The OECD publishes the Science, Technology and Industry Scoreboard (OECD, 2011a), based on national level analysis, and has recently completed a project on "Smart Specialisation Strategies for Innovation-driven Growth" (OECD, 2013a), which includes a thorough exercise of regional profiling exercise. The OECD has also developed a comprehensive methodology and database to help assessment of country positions in global value chains (OECD, 2013b). The World Economic Forum provides country comparisons based on the Global Competitive Index (World Economic Forum, 2012) and the World Bank manages a country-level benchmarking tool based on the Knowledge Assessment Methodology (Chen and Dahlman, 2005).

When planning for and designing profiling analysis, it is important to conceptualise regions not as stand-alone, isolated economies, but as open, globally connected spaces, integrated in a number of transnational value chains and connected to external markets (Dunning, 2000; Asheim and Coenen, 2006). The RIS3 guidelines published by the European Commission recommend that profiling analyses for regional benchmarking should include indicators reflecting the region's position within its national and international frameworks, as well as its multiple connections to other regions and countries.

There are a few recent examples of how systematically to analyse regional connectivity with external economic systems in a way that is meaningful and allows comparison and benchmarking. Thissen *et al*. (2013a) propose a completely new theoretical approach to measuring inter-regional and international revealed competition, and apply it to the European NUTS2 regions. They apply this measure of competition also to benchmarking sectors and regions. We should also recall in this respect the work of Benneworth and Dassen (2011), reflected in the OECD report "Regions and Innovation policy" (OECD, 2011b), which develops a regional taxonomy of global-local innovation connectivity. A first and still unique attempt to uncover trends in inter-regional connectivity through mapping co-patenting patterns is provided in Ajmone Marsan and Primi (2012).

Nevertheless, connectivity analyses of this type are quite rare and still underdeveloped. Analysis of the outward dimensions of regional economies by means of direct and EU-comprehensive mapping of inter-regional connections and associated flows of goods, knowledge and human resources, is probably the weakest element in the profiling and benchmarking literature. The main reason for this weakness is the lack of appropriate data on bilateral regional relationships and also but to a lesser extent, the need to test and improve a methodology suited to their analysis. This applies especially to trade flows, where the data are mostly at national level, and where, when regional-level information is available, it is not possible to reconstruct bilateral relationships. We believe this is a major obstacle to our understanding of how regional economic systems relate to each other.

Specifically, the export of goods and services reflects the true size of the market accessible to regional firms which is likely to be broader than the local market. Knowing the extent and characteristics of external regional markets to which a given region exports offers a more realistic and useful picture of the demand base and its competitors and would allow regional comparisons across Europe according to the role played by each region in the single market (Thissen *et al*.., 2013a).

In this paper we make an initial contribution to mapping and analysing inter-regional trade patterns, exploiting an extremely rich and innovative dataset from the PBL Netherlands Environmental Assessment Agency.

We start by considering the key issue of the integration of regional economies and market accessibility in the European area. This has persistently led the EU policy agenda and is a crucial issue in international economics, especially for studies of factor mobility, international imbalances, and shock transmission mechanisms. We believe there is substantial scope for proposing new measures of integration and market accessibility, taking regions as the relevant territorial unit of analysis. Such comprehensive and fine-grained evidence is still limited.

A second important issue in the context of regional policies and especially those aimed at promoting smart specialisation, is the relative positioning of regions in the single market in terms of their competitive strengths and weaknesses. We make an attempt to derive a richer characterisation of the system by shifting from global properties (integration) to the properties of those units that constitute the system, i.e. the regions, and developing and studying regional rankings based on patterns of connectivity of inter-regional export flows.

4. Methodology

This section defines of the main graph-theoretic concepts that apply to the context of inter-regional trade on which bases we carry out our analyses.[2] The main object of our analysis is a weighted, directed graph where the nodes are NUTS2-level regions, and the directed links are flows of agricultural goods or processed-food products. The links have direction, they are export or import links, and are of varying intensity according to the value of the traded goods.

Let *V* be a finite set of regions representing network nodes. Let *L* be a set of ordered pairs of elements of *V* representing directed links. In the context of inter-regional trade, a link going from region *i* to region *j* represents a transfer of goods from *i* to *j*. The number of elements in *V* is denoted by *n* and is referred to as network *size*. The set of regions and the set of links form the binary directed inter-regional trade network G(*V*, *L*).

The network *density* is obtained by dividing the number of actual links by the maximum possible number of such links, which, in turn, is obtained when a link is present between each possible pair of nodes. Network density provides a simple indication of the general level of linkage among nodes, measuring how far the network is from a state of completion.

A network is said to be connected if, for every pair of distinct nodes *i* and *j*, there is a *path*, i.e. a chain of consecutive links from *i* to *j*, otherwise it is said to be unconnected or disconnected. An unconnected network can be composed of smaller groups of interconnected nodes, isolated nodes or a combination of the two.

A network *component* is a maximal set of nodes all of which are either mutually reachable through paths (following the direction of links), representing a *strongly connected component*, or are reachable one-way only, representing a *weakly connected component*. A network can consist of several components, which can be ordered according to size (number of nodes). In general, a network can be said to have a *giant* weakly connected component (WCC) if the largest weakly connected component covers at least 50% of the nodes and the other components are small; it has a *giant* strongly connected component (SCC) if the largest strongly connected component covers at least 25% of nodes and the other components are small.[3]

Network components allow an immediate appreciation of the level of network integration. There may be disconnected groups in the set of nodes. Disconnected sets may imply structural segregation of nodes, divergence of development patterns, or even conflict. In our specific case, the degree to which a region can trade with other regions indicates the extent to which the original region is separated or isolated from the whole EU economy. If a region cannot trade and hence

[2] More technical and comprehensive references can be found in Wasserman and Faust (1994) and Boccaletti *et al*. (2006).
[3] For a practical example on the use of such thresholds, see Gianelle (2012).

cannot communicate with another region, then learning, support, cooperation, or influence between the two may be very difficult.

The length of the path from *i* to *j* is equal to the number of links one should cover in order to get from *i* to *j* following the link directions. The shortest path between *i* and *j* is the *geodesic*. The *average path length* (APL) of a network is defined as the average of all possible geodesics and is usually defined only within the SCC (if such a giant component is present).

The APL is usually taken as a measure of the distance between the nodes in a network. The notions of integration and distance taken together allow characterisation of network reachability. In the context of inter-regional trade, network distance can be interpreted as an indicator of increasing competitive pressure as a result of market penetration. Regional markets at a greater distance from a given export origin are more difficult to reach from such a location, so a smaller average distance indicates better market accessibility. Regions that are closer to other regions may be able to exert more competitive power in target markets than regions that are more distant. Moreover, if distances are great, it may take time for information to diffuse across the regions through economic exchanges.

The set of nodes to which node *i* is directly connected, on both entry and exit, is called the *neighbourhood* of *i*. This leads to the notion of *clustering coefficient*. The clustering coefficient of node *i* measures the extent to which the neighbour nodes of *i* are interlinked to form a densely connected group. Following Watts and Strogatz (1998), the clustering coefficient of node *i* is defined as the ratio of the actual number of links between the neighbours of *i* and the maximum possible number of these links.

The average clustering coefficient of a network is referred to by the acronym ACC. The presence of clustering signals that nodes tend to group together, forming smaller communities within the larger network. From the point of view of reachability, clustering can be thought of as redundancy of links at local level; this characteristic promotes robustness to link disconnection and also reliable connectivity based on multiple independent pathways. Notably, clustering in trade networks may play a substantial role in absorbing shocks to single regional markets within a cluster, because it allows for a reallocation of goods' flows through multiple channels.

The number of links pointing towards *i* is defined as the *in-degree* of node *i*; similarly, the number of links originating from *i* is defined as the *out-degree* of node *i*. The *total-degree* of node *i*, is the sum of in-degree and out-degree.

The degree of a node can be thought as a simple measure of network centrality. A node with high degree centrality maintains numerous contacts with other network nodes. Nodes have higher centrality to the extent that they can access and/or influence others. In an inter-regional trade network, a central node occupies a structural position that serves as a source or conduit for larger volumes of transaction with other nodes and, therefore, has large potential market access; in-degree indicates the importance of a given region as a market for other regions, while out-degree offers a measure of market accessibility of a given region.

In a weighted network, the natural generalisation of the degree of a node *i* is the node *in-*, *out-* or *total-strength*, defined as the sum of the weights of links incident in node *i*. Node strength is the simplest way of integrating information on the number of links incident in a node (degree) and their respective weights.

Another, more sophisticated way of integrating degree and link weight into a single measure is *weighted degree centrality* proposed by Opsahl *et al.* (2010). This centrality measure is given by the product of the degree and the average weight of a node's links adjusted by a tuning parameter that in our case is set equal to 0.5, meaning that having high out-degree is considered favourable. In trade networks, an indicator developed in this way will assign a positive value for both trade volume and number of commercial channels.

5. Data

In Europe, Eurostat publishes key regional statistics for the European Union and other important non-EU countries. However, crucial economic data on trade between regions are missing from European regional databases. Our analyses are based on the only presently available comprehensive dataset that describes trade between European regions according to 58 product categories (Thissen *et al.*, 2013b, 2013c). This dataset was made available by the PBL Netherlands Environmental Assessment Agency.

These inter-regional trade data were constructed without using a specific model to estimate trade patterns. This contrasts with earlier partial attempts whose estimates are based on the gravity model and on many regionally specific parameters and result in model outcomes not data. Data are crucial for our analysis since it is impossible to use model outcomes in unrelated empirical studies, since the information is contained only in the parameters of the estimated gravity model, and the related dataset is the result of this information. For instance, research on the validity of the gravity model based on data generated by the gravity model, by definition, will confirm the validity of the model. Despite its well-known limitations and analytical inconsistencies, use of the gravity model is widespread.[4]

The trade data employed in the present study were developed to fit all the information available, without pre-imposing any geographical structure on the data. The method, therefore, is 'parameter-free' and in line with more universal methodologies such as those proposed by Simini *et al.* (2012).

[4] See Simini *et al.* (2012) for an overview.

Simini *et al*. argue that parameter-free methodologies outperform sophisticated parameter estimations, remain closer to the actual data, and are less data demanding.[5]

This unique trade dataset describes all trade between NUTS2 regions, expressed in consumer prices, and for all the years in the period 2000-2010. Data also cover trade flows with the rest of the world and consumption within the region, such that total trade adds up to total production in the region. All data are consistent with the national account statistics published by Eurostat.

We consider 250 NUTS2 regions in the EU25, and focus on the year 2007. We chose 2007 because it is the last year before the international crisis affected Europe. The crisis may have resulted in time-specific effects that influence the general applicability of the analysis; therefore, it is important to choose a representative year before the crisis.

We present our analysis for two different networks, but the analysis could be extended quite easily to the other 54 product categories available in the dataset. The first network is agricultural products, comprising three categories of primary goods: agriculture and hunting; fishery; forestry (CPA/NACE codes 1, 2, 5). The second network is processed-food products, comprising food and beverages (CPA/NACE code 15). We impose a cut off on trade flows at 10 Million Euros, including in the networks only bilateral trade flows above this threshold. We impose this condition in order to remove the noise from small trade flows that do not correspond to stable commercial channels and may correspond only to one-off sales, most likely involving a small number of buyers and sellers due to the low value of goods traded.

6. Regional interconnection in the European market

The main, global topological characteristics of the inter-regional trade networks in the EU25 are shown in Table 1. The following metrics are reported: number of nodes in the network; number of directed links; network density; number of nodes in the WCC and coverage of the component in terms of percentage of total network nodes included; number of nodes in the SCC and coverage of the component in terms of percentage of total network nodes included; APL between nodes in the SCC in the actual network, denoted by the acronym APL_{SCC}; APL between nodes in the SCC in a random network of the same size as the actual network, denoted by APL_{RANDOM}; ACC of the actual network; ACC of a random network of the same size as the actual network, denoted by $ACC_{RANDOM.}$

The information presented in Table 1 describes several interesting topological characteristics of the two networks under study. Let us start by considering the agricultural products network. The first observation stems from joint examination of network density and extension of the giant components of the network, SCC and WCC. The network exhibits quite a low value for link density,

[5] See Thissen *et al*. (2013a, 2013b, 2013c) for extensive discussions on the construction, description and use of this trade database.

0.0681, two orders of magnitude lower than the benchmark value of a complete network. The actual network looks far from complete and has a sparse structure.

This might suggest that network nodes are separated and likely to be mostly disconnected one from the other. The overall network would then appear like a scattered plot of smaller sub-networks, an archipelago of remote islands with no trade relationships between them. However, a WCC exists which covers 249 nodes, in other words, all but one of the EU25 regions are interconnected by at least one direction of trade flows. Within the scope of the WCC, a SCC is also present, covering more than 87% of network nodes and revealing that 219 out of 250 regions examined are mutually interconnected through chains of agricultural trade exchanges. This provides a picture of a very integrated system, and represents quite remarkable evidence, especially if we take into account the extension of the European market, both geographically and economically, and the variety of the territories included.

Table 1 – Network characteristics, agricultural and processed-food products

Network variable	*Value (% of network coverage)*	
	Agricultural products	*Processed-food products*
Nodes	250	250
Links	4 239	14 114
Density	0.0681	0.2267
Nodes in WCC	249 (99.6)	250 (100)
Nodes in SCC	219 (87.6)	242 (96.8)
APL_{SCC}	3.0958	1.8603
APL_{RANDOM}	2.2278	1.8855
ACC	0.5725	0.5080
ACC_{RANDOM}	0.0666	0.3140

One might wonder how much effort is needed for tradable agricultural goods to reach a given target region by travelling through the interconnected system described above. This is equivalent to asking much the formally integrated network of European regions is practicable or traversable by agricultural goods, assuming that, if the number of intermediate links that products need to pass through to reach a target region is very high, the probability of this "route" being a feasible commercial channel will be small. The second observation we formulate based on the data in table 1 should answer this question.

The important comparison here is between APL in the SCC in the actual network and the same indicator calculated for an artificial network with the same number of nodes and links as the actual one, but with links randomly placed between nodes. As explained in Section 3, short average path length is a desirable characteristic for our trade network to be feasible for flows of goods. Random networks usually have particularly short APL, of the order of ln(n), and are thus taken as the benchmark in the literature (Bollobás, 1985). The actual agricultural trade network exhibits an APL_{SCC} of 3.0958, meaning that, on average, the 219 regions forming the SCC have about three links between them. This value is of the same order and only slightly above the value of APL_{RANDOM}, revealing that the actual network has short APL. The conclusion is that the interconnected system of European regions is permeable to trade flows of agricultural products.

There is a third consideration with respect to the topological characteristics of the agricultural trade network presented in Table1. The last two rows in Table 1 report the respective values of ACC of the actual network and of its random counterpart. Random networks do not exhibit relevant clustering properties and thus are taken as a benchmark for evaluating the level of clustering in experimental networks. Our network has an ACC equal to 0.5725 which is 8.5 times the value of ACC_{RANDOM}. This result reveals that the agricultural trade network shows relevant clustering, i.e., within the overall interconnected European structure, regions tend to form smaller and relatively more interconnected and more cohesive communities. This is not surprising and is likely to be the result of the complex geography of Europe and especially the presence of national boundaries which still represent a barrier to international trade and induce denser relationships within than between countries.[6]

Nevertheless, the observed presence of a non-negligible community structure in the network, revealed by high clustering, represents an emerging feature of inter-regional agricultural trade whose exact properties and implications should be the object of further research. Their study is beyond the scope of the present research, but represents a promising and interesting investigation that would provide a better understanding of the actual shape and functioning of the European single market taking regions as the unit of analysis.

When considered jointly, the three main results presented above show that the agricultural products network fits with the description of a *small world,* or network model characterised by nodes that are easily reachable, one to another, via a minimum assembly of links (Watts and Strogatz, 1998). A small-world network of inter-regional trade is an integrated system characterised by local clustering, with a relatively small number of long-range connections that act as shortcuts between different clusters in regions that otherwise would be quite remote from one another. An SCC guarantees the existence of connecting paths between all possible pairs of regions, while short distance indicates that regional markets can be accessed, with little effort, by other regions. Clustering indicates robustness to link disconnection and reliable connectivity based on multiple independent pathways (White and Houseman, 2002).

Next we examine the processed-food network. Link density is around three times higher than in the agricultural network, but is only a quarter of the density of a complete network. Inter-regional trade

[6] On the effect on European trade of national borders, see Chen (2004).

flows of processed-food goods valued at over 10 million Euros are more numerous and widespread than in the agricultural network, leading to a denser and more intertwined network in which all 250 regions are interconnected and 242 are mutually reachable through chains of import and export flows.[7] We can conclude that the system is almost completely integrated, with no relevant subgroups of regions excluded from the single market.

The average distance between regions in the mutually interconnected core of the system is 1.8603 links, a very small value, slightly less than in a benchmark network with randomly placed links. European regions on average are very close to one another in the trade network, with the result that each regional market for imports and exports of food products is fairly accessible from any other region belonging to the single market.

Similar to the agricultural network, regions tend to form more densely interconnected sub-groups embedded in a larger network, revealed by the average clustering coefficient of 0.508. Interestingly, the processed-food network is less clustered than the agricultural products network, suggesting that geographical distance and/or national borders play a smaller role in this context.

The results discussed so far constitute evidence of the importance of in-depth analysis of the outward dimension of regional economies for the design, implementation and evaluation of smart specialisation strategies. The integration and practicability of European trade networks reveals that regions are mostly embedded in the same single system of cross-border exchanges. Relationships between European regions in the tangled web of trade create interdependencies that cannot be ignored in analyses of the sources of regional economies' competitive advantage and the limits to and potential for expansion of domestic activities. Our results reveal also that regional markets for international products are mostly reachable and interconnected, thus offering a fundamental rationale for strategic action aimed at expanding the market horizon of regional firms.

7. Regional positioning and rankings

The results for the integration and practicability of European inter-regional agricultural and processed-food goods networks presented above constitute a basis for exploring how single regions are positioned within the interconnected system. Understanding how central/peripheral regions in the network are and how well and widely interconnected they are, can provide important support for policy making, especially with respect to the identification and analysis of potential priorities for investment in and public funding for innovation and research, which are crucial for the smart specialisation process.

[7] This is not a surprising result. It may simply be because industrial transformation adds value to agricultural products to produce a wide range of processed-food products that then are traded at higher prices than their individual raw materials.

The focus now shifts to differences among regions in the same network. Because regions are part of the same single system of trade exchanges does not mean they occupy similar positions, based on similar connectivity patterns, but it is a basis for inter-regional comparisons. In practice, we can assess regional positions by calculating different synthetic measures of node centrality in the network. The basic idea is that the more central the node-region in the network, the more prominent will be its role in the system and in the market and/or the greater will be its advantage over other nodes-regions in relation to number, intensity, variety and reach of trade exchanges.

There is no single method that can be used to define and assess network centrality. Given the specific context of the present study, we chose to focus on three different indicators of centrality. Reading of and interpreting the complementary information provided by these indicators should capture relevant information about the competitive positioning of regions which can be fed immediately into work on RIS3.

The three indicators of regional centrality we chose are:

- **Out-degree** or number of export destinations (regions): this captures the reach of regional export in Europe and also the diversification and sophistication of the regional export strategy;
- **Out-strength** of export links or total value of exports: this provides information on the magnitude of total export flows and, hence, the incidence of regional exports in Europe and regional critical mass in the market;
- **Weighted out-degree centrality**: this is the weighted product of the first two indicators, or the interaction between out-strength and out-degree; the resulting indicator combines a preference for higher export volumes with a preference for diversification of export destinations.

This allows regions to be ranked according to the values of each of these indicators and compared within and across rankings. Although we obtained complete rankings for 250 NUTS2-level regions of Europe, in what follows we focus on the top and bottom ends of the rankings in order to show how to read evidence; the interpretation can then be extended to all regions. Table 2 presents the regions in the top five and bottom five rankings for the agricultural products network. Table 3 presents the regions in the top five and bottom five rankings for the processed-food products network.

Based on the information on the agricultural products network reported in Table 2, we observe that there are persistencies in regional rankings across the three indicators, showing that the indicators are correlated to some extent. Among the top-five regions, the Spanish region of Andalusia and the Dutch region of South Holland consistently occupy first and second positions respectively, revealing outstanding performance in total value of exports and number of regional markets served. This is consistent with the leading role in agriculture of these two regions found in Thissen *et al*. (2013a). Lombardy in Italy, Castile and León and Catalonia in Spain appear twice in the rankings and occupy 3rd, 4th or 5th position depending on the indicator considered. Among the five lowest ranked regions, the French region of Corsica and the Italian region of Aosta Valley both appear in all three rankings, although in different positions; the British region of Tees Valley and Durham is ranked low for both out-strength and weighted out-degree centrality.

Table 2 – Regional positions according to centrality indexes, agricultural products

	Top five regions			***Last five regions***		
Rank	*Out-degree*	*Out-strength*	*Weighted out-deg.*	*Out-degree*	*Out-strength*	*Weighted out-deg.*
1.	Andalusia (ES)	Andalusia (ES)	Andalusia (ES)	Corsica (FR)	South Yorkshire (UK)	Tees Valley and Durham (UK)
2.	South Holland (NL)	South Holland (NL)	South Holland (NL)	Anatoliki Makedonia Thraki (GR)	Tees Valley and Durham (UK)	Saarland (DE)
3.	North Brabant (NL)	Lombardy (IT)	Castile and León (ES)	Dytiki Makedonia (GR)	Saarland (DE)	Åland (FI)
4.	Castile and León (ES)	Vest for Storebaelt (DK)	Lombardy (IT)	Voreio Aigaio (GR)	Aosta Valley (IT)	Aosta Valley (IT)
5.	Catalonia (ES)	Emilia-Romagna (IT)	Catalonia (ES)	Aosta Valley (IT)	Corsica (FR)	Corsica (FR)

The rankings discussed in this section provide descriptive information on the relative positioning of NUTS2-level regions whose differences in the network are determined only by trade connectivity patters. The variation in these patterns that gives rise to the observed centrality rankings may derive from several characteristics of the regional economy and society.

Regions at the top of the rankings often have a large surface area (e.g. Andalusia, Castile and León, Catalonia), allowing for more agricultural activity; some regions have expertise in agro-food production (e.g. the Italian regions of Lombardy and Emilia Romagna and the Dutch regions). Regions in the bottom of the rankings also exhibit specific characteristics. Some are islands (Åland, Corsica, Voreio Aigaio), most have small territories and populations (e.g. Aosta Valley), some have a strong industrial tradition, often dating back to the origin of European industrialisation (Saarland, Tees Valley and Durham).

The causal link between regional characteristics and the reported rankings needs further investigation by researchers and policy makers interested in applying this kind of analysis to specific cases. Systematic exploration of this relationship is beyond the scope of the present paper. It should be stressed also that the discussion of relative regional positioning in this paper is based solely on the results for a few specific activities in the agro-food value chain. Strategic policy choices about the activities or economic areas to be prioritised in the context of RIS3 and in regional development more generally, should be based on more comprehensive comparisons across both activities/sectors and regions. This would give a more complete picture of the comparative strengths and weaknesses of regional economies.

However, based on the analysis in this paper, we can derive some interesting, although preliminary and broadly-framed implications for policy, and especially for the design and assessment of RIS3. In particular, we would expect the regions at the top of the rankings to include agriculture-related priorities in their RIS3, or at least that their strategies and development plans should reflect the potential synergies of others' economic activities with their agriculture production bases. Similarly, regions ranked lowest would be expected to prioritise different economic areas. Agriculture-related priorities in these regions should either be supported by strong arguments counterbalancing the lack of international critical mass, or be framed in terms of highly-specific, truly unique market niches or knowledge domains connected to production technologies. It is responsibility of the region to identify and justify their priority choices.

Table 3 – Regional positions according to centrality indexes, processed-food products

	Top five regions			***Last five regions***		
Rank	*Out-degree*	*Out-strength*	*Weighted out-deg.*	*Out-degree*	*Out-strength*	*Weighted out-deg.*
1.	North-Brabant (NL)	North Brabant (NL)	North Brabant (NL)	Corsica (FR)	Corsica (FR)	Corsica (FR)
2.	South-Holland (NL)	Lombardy (IT)	Lombardy (IT)	Ionia Nisia (GR)	Ionia Nisia (GR)	Ionia Nisia (GR)
3.	North-Holland (NL)	Île-de-France (FR)	Île-de-France (FR)	Aosta Valley (IT)	Aosta Valley (IT)	Aosta Valley (IT)
4.	Gelderland (NL)	Catalonia (ES)	South Holland (NL)	Malta (MT)	Malta (MT)	Malta (MT)
5.	Oberbayern (DE)	South and East Ireland (IE)	South and East Ireland (IE)	Åland (FI)	Åland (FI)	Åland (FI)

Table 3 presents the regional rankings for the processed-food networks. Persistencies across rankings are present and even more pronounced than in the agricultural production network. The Dutch region of North Brabant, which is known for its strong food procession industry, consistently leads the three rankings; Lombardy, the French region of Île-de-France, South Holland and the region of South and East Ireland appear twice among the first five regions. The lowest five positions are the same across all indicators, with last positions occupied by the Finnish region of Åland, Malta, Aosta Valley, the Greek region of Ionia Nisia, and Corsica.

The lowest ranked regions seem strongly associated with the condition of being an island (Åland, Malta, Ionia Nisia, Corsica). Being an island seems to be a clear disadvantage for processed-food exports. Among the top-ranked regions, it can be observed that the performance of several Dutch regions is outstanding. Notably, the rankings for agricultural products and processed-food show some clear correlation. The Dutch regions of South Holland and North Brabant rank very high in both the upper and lower segments of the agro-food value chain, and several other Dutch regions appear in the top ranking of both segments. The Netherlands occupies a prominent position in Europe in this economic area, thanks to intensive utilisation of its agricultural land, employment of advanced technologies, and simultaneous presence of multinational firms in the food industry and efficient logistic infrastructures. Lombardy and Catalonia demonstrate very strong international positioning along the agro-food value chain.

Several policy implications for RIS3 can be derived on the basis of the results highlighted so far. Being an island should be taken into account as a factor potentially hampering the development of an internationally competitive food industry. Consequently, insular regions should consider articulating their food-industry-related priorities (if any) in connection with other activities (e.g. tourism), and clearly identifying and specifying unique opportunities for knowledge-based development. Alternately, other economic areas should be prioritised. Regions with a strong positioning in the food-industry should reflect this advantage in the strategic work on RIS3.

Special and interesting cases for discussing the policy implications of this analysis are Andalusia and, to a lesser extent, Castile and León. These regions rank high in the lower segment of the agro-food value chain, i.e. agricultural production, but in contrast to other regions of Europe this result is not matched by a good performance in the upper segment of the value chain, the food industry. Section 8 discusses the case of Andalusia.

8. Policy implications for RIS3 design: the case of Andalusia

As indicated in the introduction, a place-based approach to policy making requires appropriate analytical tools to allow a good understanding of the regional context. In the case of smart specialisation, this means that R&D and innovation policy decisions should be supported by more comprehensive comparisons of regional performance across a wider range of indicators and economic activities than those proposed in this paper. Nevertheless, we believe that these first, exploratory results provide interesting suggestions for policy making. Andalusia is a good case study in this respect.

Andalusia leads the three rankings for the agricultural products network, revealing outstanding performance in Europe in exports of non-processed primary agricultural goods. If we examine the results in more detail, we see that in the year 2007 Andalusia had out-strength equal to 6.6 billion Euros obtained by summing inter-regional export flows equal to or above the threshold of 10 million Euros. In the same period, the second highest-ranked region in Europe, South Holland, had out-strength of 5.2 billion Euros, while the fifth ranked region, Catalonia, totalled 2.9 billion Euros, around 45% of the out-strength of Andalusia. Andalusia's exports go to 111 regional markets in

Europe, each worth at least 10 million Euros. South Holland had 103 export destinations of this value, while Catalonia had only 61.

In the processed-food products network, Andalusia ranks 8th for out-strength, with 11.5 billion Euros exported in the EU25, slightly more than a half of the outflows generated by North Brabant, the region ranked first, which achieved 21.9 billion Euros. For export destinations or out-degree Andalusia is ranked 20th, with 146 regional markets worth at least 10 million Euros each against 203 markets served by North Brabant.

A first and perhaps obvious observation that can be derived from these results is that the region of Andalusia has a strong position in the European agricultural market, and a diversified export strategy. Therefore, agriculture, in principle, can be considered a key, strategic sector for the Andalusian economy. The second observation is whether this result was taken into account by regional policy makers in the process of designing and implementing the current framework for innovation and development policies.

We investigate this by analysing Andalusia's current innovation strategy, the "Plan Andaluz de Investigación, Desarrollo e Innovación 2007-2013 (PAIDI)" (Junta de Andalucía, 2007). In this document, agriculture is mentioned as a potential sector to benefit from public support, but only together with 12 other sectors which together cover almost the whole spectrum of economic activities. Analysing the current policy framework from the RIS3 perspective, it can be concluded that the current strategy does not prioritise appropriately.

However, the figures for Andalusian spending on R&D and innovation in 2006-2012 highlight agricultural R&D as a *de facto* priority for research and innovation policies. Public spending on R&D and training in agriculture and fishery was 64.2 million Euros in 2006, accounting for 17.4% of total public spending on R&D. This balance-sheet entry was 67.1 million Euros in 2007, and 76.5 million in 2010, an increase of 19% over four years, although the incidence on total R&D spending in 2010 decreased to 14.1%. Complete figures for 2011 and 2012 were not available at the time of writing, but, according to estimates, agricultural R&D should remain at above 70 million Euros. Hence, although the current strategic framework in the field of R&D and innovation policies does not put agriculture as a key priority, actual spending numbers show that the sector has been given special attention. This raises important questions about the quality of the current strategic framework and, especially, about the effectiveness of the resources invested.

Another clear implication of the network analysis is that the importance of agriculture should be considered in the on-going debate and process of RIS3 design for the period 2014-2020. It could be argued also that a clear prioritisation is needed in the new strategic framework for smart specialisation which could be built around agriculture and could exploit the potential for innovation in related sectors.

A final important consideration is that Andalusia might have substantial reserves of growth and competitiveness potential in the food-industry which currently is relatively weak compared to the agricultural sector. This potential could be exploited by extending the regional value chain by integrating higher-value-added activities in the food-processing industry, which, in turn, could exploit the advantage of proximity with strong and outward-oriented local production of prime materials.

Such an integration process is far from straightforward because it cannot be achieved through the application of new techniques or technology, nor can build entirely on existing assets. It will likely require the development of new entrepreneurial capacity in which the crucial factors will be information and knowledge about international food markets and the capacity to study and understand the tastes of foreign consumers. The development of these factors could be supported by a well-focused, evidence-based RIS3.

9. Conclusions

This work presents a new methodology to assess the outward connectivity of regional economies in the EU through trade relationships, and provides empirical evidence on trade in agricultural and processed-food products. The motivation for this study is the renewed EU cohesion policy framework for the period 2014-2020, especially smart specialisation policy aimed at enhancing competitiveness through targeted investment in research and innovation. The paper provides a new practical tool to help develop the knowledge base required for a thorough identification of economic activities where regions exhibit competitive strengths or weaknesses. Based on the application of this original methodology to empirical data, we can derive several lessons for policy.

The paper adopts a network analysis approach. The main object of analysis is a network of inter-regional trade flows in the EU25 in the year 2007. Unique trade data were taken from the PBL Netherlands Environmental Assessment Agency database and mapped onto weighted directed networks in which the nodes represent regions and the links are flows of goods. Several characteristics of the networks are measured and presented in a structured manner in two distinct conceptual blocks: emerging global properties of the European trade web, and a set of indicators quantitatively defining the position of individual regions within the system.

On a global scale, the EU25 trade networks of agriculture and processed-food products reveal that regions are mostly embedded in the same single system of cross-border exchanges, with no relevant subgroups of players left out of the single market. Regional markets for international products are shown to be mostly reachable and interconnected, thus offering a fundamental rationale for strategic action aimed at expanding the market horizon of regional firms.

The analysis of network centrality rankings provides a multi-dimensional assessment of regional positioning that can be immediately related to size, variety and reach of export activities within Europe. Based on the analysis, some preliminary and broadly-framed implications for the design of RIS3 can be derived. In particular, we would expect the top-ranked regions to include priorities related to agriculture or the food industry in their RIS3, or at least for their strategy or development plans to reflect an accurate analysis of the potential synergies of others' economic activities with these production bases. Insularity should be taken into account as a factor potentially hampering the development of an internationally competitive food industry. Island regions should consider articulating their potential priorities in the food industry connected to other activities, such as tourism; alternately, other economic areas should be prioritised.

The methodology proposed in the paper provides a natural basis for prioritising areas for public investment, as required by the European Commission guidelines on smart specialisation. It could serve as a new instrument to be included in the policy making toolbox, both in order to feed RIS3 design with evidence about competitiveness positioning and to evaluate current regional innovation strategies or the consistency of existing RIS3 priorities with actual regional positioning in Europe. A practical example is provided by the case of Andalusia.

The main limitations of the methodology and results presented in the study fall into three categories. First, comparison of trade networks for other economic activities should be performed. Ideally, a full range of industrial products and services should be considered in order effectively to support selective choices. The analysis in this paper provides only a partial picture, hence policy conclusions should be taken as tentative at this stage. Second, networks should be mapped in time in order to capture their evolution. This is important to understand the persistency of regional rankings, and to capture important phenomena related to emergence or decline. Third, the causal link between regional characteristics and the reported rankings should be specifically analysed. Development of research along these lines constitutes a promising and challenging avenue for the community of researchers and practitioners interested in the future of regional innovation and industrial policy in Europe.

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Title: **Smart specialisation in the tangled web of European inter-regional trade**

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Abstract

This work presents a new methodology to assess the outward connectivity among regional economies in the EU and derives policy lessons for the design of regional innovation and competitiveness-enhancing strategic frameworks, with particular reference to research and innovation strategies for smart specialisation (RIS3).
We study the network of inter-regional trade flows in the EU25 in the year 2007. Trade data are taken from the PBL Netherlands Environmental Assessment Agency database and mapped onto weighted directed networks in which the nodes represent regions and the links are flows of goods. We measure several structural characteristics of the networks, both global properties and centrality indicators describing the position of individual regions within the system.
European regions appear to be mostly integrated in the European single market. Strengths and weaknesses of individual regions are discussed based on rankings obtained from network centrality indicators. Specific policy implications in the context of RIS3 are derived in the case of the Spanish region of Andalusia.
We show the potential of the methodology for providing a new family of indicators of the external connectivity of regional economies that can be used by regions wishing to develop their own RIS3 for 2014-2020, as required by the EU in the context of the new cohesion policy framework.

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