Technological Forecasting & Social Change 79 (2012) 1548–1567

Contents lists available at SciVerse ScienceDirect

Technological Forecasting & Social Change

# The structure of inter-industry systems and the diffusion of innovations: The case of Spain

María Semitiel-García, Pedro Noguera-Méndez *

*University of Murcia, Murcia, Spain*

ARTICLE INFO

*Article history:*
Received 18 March 2011
Received in revised form 30 January 2012
Accepted 10 April 2012
Available online 26 May 2012

*Keywords:*
Inter-industry linkages
Scale-free networks
Core–periphery structure
Network analysis
Innovation diffusion

ABSTRACT

This paper focuses on the role of inter-industrial structures and the position of economic sectors in them for the diffusion of knowledge and innovation. Network Theory and Social Network Analysis have been applied to analyze the structure of the Spanish Input–output system and its evolution over a thirty-five-year period. The structural analysis conducted tests the existence of a Scale-free topology and also includes the identification of sectors acting as hubs or super-spreaders, which make up the core of the system. Scale-free networks correspond to structures that allow for faster and more efficient diffusion processes that are enhanced when initiated in hubs. As a concluding remark, this paper puts forward a proposal for interventions to attain a higher incidence in the national innovative capacity and in the development process.



## 1. Introduction

Even if Network Theory (NT) is still a novel methodology in economics [1,2], it is increasingly accepted that the economy is a complex system that requires deep systemic analyses, starting from its topological characteristics [3–5]. More precisely, understanding the structure and dynamics of economic networks requires the study of the structural properties of the underlying interaction networks and their dynamics [6]. This paper analyzes the structure and evolution of inter-industry systems in Spain, from NT and Social Network Analysis (SNA). It adopts a systemic approach and the structural change definition stated in Saviotti and Gaffard [7]: "In the past, the concept of structural change has been interpreted in the economics literature as a change in the weights of different sectors. However, today it is increasingly evident that a broader concept of structural change is required. In a systemic framework, structural change can be defined as a change in the structure of the economic system, that is, in its components and their interactions".

When this structural view is applied to innovation processes, it is assumed that actors acquire and develop overlapping and diverse knowledge resources through interactions with other actors, and that the newly acquired knowledge can be converted into new products, patents and other tangible forms [8]. Knowledge is more likely to be transferred between organizations that make chains or systems than through independent organizations [9]. In general terms, knowledge flows between two actors are made easier when the actors are embedded in a dense network of third-party connections.

This is the case of economic sectors embedded in dense production networks and exchanging knowledge and innovation. Although the processes of production and of innovation differ in important respects "they are also mutually interdependent" [10]. In accordance with Hauknes "At the firm level, it should be evident that for most firms, their relations with customers, competitors and suppliers are the most significant links to their environment, to the extent that these agents constitute the major dimensions of this environment. It is not unlikely that these immediate relations shape the major learning modes for a majority of firms" [11]. In many innovation surveys, as in OECD surveys [12], firms indicate that suppliers, customers and competitors are

* Corresponding author at: Department of Applied Economics, University of Murcia, 30100, Murcia, Spain. Tel.: +34 868887930; fax: +34 868883745.
*E-mail addresses:* mariase@um.es (M. Semitiel-García), pedrono@um.es (P. Noguera-Méndez).

0040-1625/$ – see front matter 
doi:10.1016/j.techfore.2012.04.010

'highly important' sources of knowledge for innovation. User–producer interactions, joined through inter-industry linkages, play a fundamental role providing embodied knowledge flows in incremental innovation and in the learning process [10,13,14]. In the same line, Schmookler [15] points out that "the best way to improve an industry's technology is often to improve the inputs it buys from other industries".

Even if not all user–producer relationships promote innovative activities [10], all of them constitute opportunities to increase the efficiency of policy interventions. The ability to take advantage of those opportunities depends on the structure of production networks. Structure matters, but there is a diversity of them that shapes dense networks, and Scale-free is outstanding among them. The role of topology in the study of the diffusion of innovations and of the effectiveness of innovation strategies is emphasized by the picture emerging from the system of economic interactions. At the same time, an innovation flow may die out on the same network immediately or persist for a considerable time, depending on the sector where it was originated. We know that our knowledge about the interactions that allow and promote innovation flows will improve by going in depth into inter-industrial structures, with its policy implications. The availability of a considerably long time series of Input–output Tables (IOT) should not be passed by. A structural analysis of inter-industry networks would contribute to the understanding of how innovation flows, to identifying highly connected sectors, named hubs or super-spreaders, that speed up the process, and to improving the design of interventions. In the case of Spain this is particularly relevant because of its innovation backwardness, its efficiency problems and the lack of effectiveness of its innovation policies.

Research on the impact of innovation on productivity growth and on other economic variables, by Input–Output (IO) analysis, was initiated by Terleckyj and Scherer, who assume that R&D is indirectly incorporated by purchasing intermediate inputs [16–18]. For DeBresson [19] IOT can serve as economic maps that indicate which are the paths of least resistance for the industrial diffusion of the technologies when the analysis is focused on market relationships and on the accumulation of technological knowledge, through experience based on the circulation of goods and services and on the process of learning by doing. "In order for a new technology already adopted by industry *i* to be subsequently adopted by industry *j*, it is preferable that industry *j* be in *direct contact*, as a client or as a supplier, with industry *i*. In other words, the two industries must be directly linked in an input–output table by a supply–demand relationship". DeBresson remarks that the information embodied in IO interactions is particularly useful for the analysis of the productive structure of the whole economy [19–21].

A new research line was opened up by Leoncini et al. [22] with the identification and study of Technological Systems by combining IO and R&D data and applying NA [23–26]. According to Montresor and Vittucci [25], IO coefficients crucially affect learning by interacting and the entailed knowledge networks that firms establish in innovating. More specifically, IO matrices map inter-sector flows of goods and services which shape the inter-sector diffusion of innovation by channeling and driving both embodied and disembodied innovation flows and the knowledge embedded in the exchanged goods and services. Their work fits into a wider field that considers that organizations acquire knowledge through interactions with other actors, making chains and systems and explaining that knowledge and innovation spread through intermediate trade linkages [8,9,25,27–29].

Our argument is also in line with other relevant pieces of research. This is the case of the literature of systems of innovation studying system failures, with the focus on missing connections to support knowledge processes through interactive learning [30–33]. A system failure policy implies that the framework conditions for a better diffusion and adoption process taking place across the structure of economic activities should be set. Actors supplying knowledge and innovation through sales and also users and consumers of goods, receiving information and probably adopting innovations through them should be taken into account.

The present paper is placed in the above literature both for its objective and its methodology. However, its focus differs as it is the structure of inter-industrial systems. We do not focus on direct relationships between two particular sectors but on the chains and sub-systems that are making up the whole inter-industrial structure. The structure and evolution of intermediate trade relationships in Spain in the period 1970–2005 using IOT are analyzed because the constituting networks that represent inter-industrial systems push production systems into the open [34,35] and act as a platform for interactions that ease learning and the processes of knowledge and innovation diffusion. The study of its structure implies a first necessary step, not addressed in the literature, before studying more specific topics affected by it. It is valuable not only for scholars but also for policy makers because its results relate to productivity and the national innovative capacity, and hence to the enhancement of development [36].

This paper raises the following questions: Does the inter-industry network in Spain show a Scale-free topology where a core and a periphery can be identified? How has it evolved in the period 1970–2005? Can hubs, or super-spreaders, sectors be identified? Are there specific strategies that can be proposed from a relational analysis to improve the diffusion of ideas, knowledge and innovation? By answering these questions this paper aims to fill a void in the literature by studying the relevance of structures for diffusion processes, particularly for the diffusion of innovations through inter-sectoral interactions. In doing so, this paper is methodologically coherent, as the economy is viewed as a complex system, and systemic methodologies are applied (SNA and NT). Following this structural view, the Scale-free topology of inter-industry networks has been analyzed and a core and a periphery have been identified; results also indicate that the core–periphery structure is consolidated and that there is a set of sectors in the core with a permanent character in the period considered. Hubs have also been identified, opening up a discussion on the suitability of the sectors which innovation policies are being directed at. Through these results, this paper offers novel contributions to the methods of identifying core–periphery networks, the analysis of innovation flows between economic sectors by using IO data, the design of public and private interventions that would enhance a more efficient diffusion of knowledge and innovation, and the methods to verify whether the selected sectors in innovation programs are the most appropriate in terms of scope and speed when a systemic effect is intended.

The paper is organized as follows: Section 2 explains the most relevant theoretical matters and the methodology followed; Section 3 presents the Spanish context in the period analyzed and the data used; Section 4 contains the empirical analysis