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ICT technologies in Europe: A study of technological diffusion and economic growth under network theory

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ABSTRACT

The sector of Information and Communication Technologies (ICT) is one of the key instruments for the development of an economy. The literature emphasizes its capacity for both increasing productivity and generating new sources of income and wealth (Colecchia & Schreyer, 2002; Jorgenson & Stiroh, 1999 among others). Traditionally studies on the ICT sector have focused on the analysis of its economic impact, but not on its capacity as a "bridge" for information and knowledge flows across the economic network. Following Burt's approach (1992) on structural holes, the organization of the economic network defines where and for whom new opportunities lie. The structural hole methodology allows to analyze the capacity of the ICT sector as an enabler of technological diffusion and innovation. The results show that the European ICT sector not only is important for its intermediary role in the flow of information across the economic network, but also for its low level of dependency on other sectors.

1. Introduction

Over the last decade a large number of studies have tried to unveil the role of Information and Communication Technologies (ICT) in economic development and productivity growth (Brynjolffson & Hitt, 2000; Colecchia & Schreyer, 2002; Jorgenson & Stiroh, 1999; Oliner & Sichel, 2000; for a recent survey see Kretschmer, 2012).

The potential of ICT relies in the fact that they are *general purpose technologies* (Bresnahan & Trajtenberg, 1995) whose main features are their fast path of technological improvement, their pervasiveness across the full economy and their role as innovation-enablers. Thus, ICT allow to develop closer links between firms, their customers, suppliers and collaborative partners. They also make possible the reduction of geographical barriers. Moreover, they facilitate the creation of new knowledge and its faster diffusion through more efficient processes of information transmission, both within and between firms and sectors (Kretschmer, 2012).

A proper analysis of the role of ICT, as drivers of knowledge flows and catalysts of innovation throughout the economy, requires taking into account intersectoral relationships. Many innovation studies have then relied on input–output (IO) analysis (see the pioneering works of Terleckyj, 1974; Scherer, 1982, among others). In this same line, several papers have approached the economic linkages of the ICT sector using IO tables (Roy, Das, & Chakraborty, 2002; Rohman, 2012, 2013; Schreyer, 2001; Xing, Ye, & Kui, 2011; Heng & Mugan, 2013, among others). However, the traditional input–output scope

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does not take into account the qualitative importance of the industrial linkages structure which is essential in the technological diffusion.

In this paper, such an approach is combined with network theory and Burt's concept on structural holes (Burt, 1992).

The starting basis of this paper is the identification of the flows of goods among the sectors of the economy as the linkages of the productive network. By analyzing the (relative) position of a sector in this network and, hence, the relationships it establishes with other industries, it is possible to approach its capacity for innovation generation and diffusion. As Lundvall (1992) and Edquist (1997) pointed out, innovation is by no means an isolated process but, on the contrary, it emanates from the interaction and learning that takes place between innovative organizations.

Nonetheless, there are some considerations to take into account when identifying the intersectoral flows of goods with the links of the economic network and its meaning in terms of innovation diffusion. In the first place, while the flows of goods between two sectors might be small in size, they might be relevant for innovation diffusion and knowledge transmission. In the second place, the use of some goods might be widely spread across the economy, but this might have few or no implications on the quality and effectiveness of innovation diffusion (García, Morillas, & Ramos, 2010; Papaconstantinou, Sakurai, & Wyckoff, 1998; Semitiel-García & Noguera-Méndez, 2012; Soofi & Ghazinoory, 2011).

Given this, the approach used in this paper takes into account not only the size and number of flows of goods between sectors but also the type of linkage in terms of information provision. According to Burt (1992) the relationships of an individual (enterprise) do not provide him with the same information and opportunities, and hence, do not have the same relevance for knowledge transmission and innovation diffusion. In particular, Burt distinguishes between redundant and non redundant connections, the latter being defined as those links that provide access to varied information and therefore allow to gain a competitive advantage. Non redundant contacts are connected by, what Burt calls, structural holes: "there is a structural hole between two people (firms) who (which) provide non redundant network benefits" (Burt, 1992, p. 19).[1] Hence, what matters for any individual (firm) is to have a network rich "in structural holes, and so entrepreneurial opportunity, and so information and control benefits" (Burt, 1992, p. 48).

Within this context, the aim of this paper is to analyze the extent to which the ICT sector acts as a *bridge* that facilitates the spread of *relevant* information and knowledge flows through the productive sectors of the economic network. In order to assess the relevance of information flows between sectors, Burt's approach on structural holes (Burt, 1992) is applied in the framework of input–output analysis and network theory. Empirical evidence is drawn from data on IO tables for the European Union (EU) over the period 2000–2007.

The performance of the ICT sector in the EU is extensively described in the latest Predict report by the Institute for Prospective Technological Studies (2012b). The most recent figures available indicate that the EU ICT sector accounted for 4% of EU Gross Domestic Product (GDP) and 2.7% of total EU employment in 2009. The generation of value added concentrated in ICT services, with more than 90% of the sector's value added produced by ICT services and, in particular, by Telecommunications and computer programming, consultancy and related activities.

The ICT sector is highly intensive in research and development (R&D) compared to the rest of the European economy: R&D intensity in the ICT sector, measured by the ratio of R&D expenditures in value added, was more than four times the European average in 2009 (5.3% versus 1.2%).

Regarding the performance of the EU ICT sector during the crisis, the report highlights the *resilience of ICT services*: between 2008 and 2009, ICT manufacturing value added decreased by 30% compared to a 4% decrease in ICT services.

The report also reveals an increasing gap between the United States (US) and the EU in ICT performance: not only does the US ICT sector lead on all figures (value added, R&D investment, and labor productivity) but also it manages to keep on growing in spite of the crisis.

The paper is organized as follows. Section 2 presents the methodological approach providing some basic ideas on input–output analysis, followed by the description of Burt's concept of structural holes (1992) and the necessary analytical tools. Section 3 describes the data used in this paper together with the definition of the ICT sector. Section 4 presents some results about the strengths and weaknesses of the European ICT sector, followed by some concluding remarks.

2. Methodological approach

2.1. Basics of input–output tables

Input–output tables describe a complete picture of the flows of goods and services in an economy for a given year (Leontief, 1951). They detail the relationships between producers and consumers as well as the interdependencies between sectors.

Fig. 1 shows the general structure of an input–output table. The rows gather how the output of each sector is distributed among the other industries. The columns describe how each sector obtains its required inputs from the others. The first quadrant (Q1) represents the flows of products between sectors. These products are produced by one sector and used by others as inputs in their production process. For this reason, they are called inter-industry flows or intermediate demand. The second quadrant (Q2) includes the final demand, that is, the demand of non-industry consumers (like households,

[1] Words in brackets are not included in the original citation but they have included by the authors in order to clarify the sentence.