The Network Structure of Knowledge: a sectoral analysis of work skills

Davide Consoli [*]
davide.consoli@ingenio.upv.es

Elena M. Tur
elmatu@ingenio.upv.es

INGENIO, CSIC-UPV (Spain)

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1. Objectives and goals of the study

The present paper elaborates an empirical study of the knowledge base of 285 industrial sectors in the United States (US) over the period 2002-2012. While much of the existing research on the dynamics of industrial sectors is built on aggregate characteristics, this paper focuses on the repertoires of skills that workers use when performing job tasks (Autor, 2013). Our goal is to elaborate an analysis of how different forms of know-how characterise industrial sectors by addressing three key questions:

(1) What are the structural properties of skill combinations embedded in the occupations of industrial sectors?
(2) What patterns of skill specialization and diversification emerge?
(3) What is the relation between these network properties and indicators of economic performance such as productivity?

This study adds to existing work on industrial dynamics by portraying structural aspects of sectoral evolution in a way that has not been attempted so far, neither conceptually nor

[*] Corresponding author: davide.consoli@ingenio.upv.es

empirically. For what concerns the former, we portray skills as characteristics that combine with each other in uniquely distinctive ways within sectors, akin to a genetic code. This, we argue, is a rather original account of the relational and distributed nature of knowledge. For what concerns the empirical strategy, our analysis shows that the skill content of occupations generates bipartite networks that reflect the know-how that industries actually use. This novel approach to the representation of the division of labour holds the promise of uncovering several, hitherto ignored, aspects of the dynamics of knowledge underpinning industrial organization. On the whole we expect such an analysis to elucidate empirical regularities that are useful for understanding the association between and industry's knowledge base and its economic performance.

2. Theoretical background

The conceptual foundations of this exercise are in the area of innovation studies, in particular the tradition of empirical works on the role of specialization and division of labour in the development of industry life cycles (Pavitt, 1984; Malerba and Orsenigo, 1996). Common to these works is the idea that sectors are characterized by systematic and persistent heterogeneity which reflects differential ability in creating and using knowledge. This literature uses various proxies for capturing industry knowledge base such as R&D intensity (e.g. Castellacci and Zheng, 2010; Cohen and Levinthal, 1990), accumulated R&D (Nooteboom et al., 2007) or scientific inputs (Breschi et al., 2000). We argue that these characteristics reflect only indirectly the intrinsic qualities of the learning process and of the organization of knowledge. The alternative proposed here is to filter the analysis of industry knowledge base through the reality of labour markets, and to identify simple but empirically testable signatures of structural properties of sectoral know-how.

Drawing on the view that industrial sectors are populations of activities defined by the development and use of knowledge for strategic objectives (Richardson, 1972), we set out to capture specific configurations of sectoral knowledge bases by analyzing employment structures and the associated skill bases. The underlying conceptual proposition is that employment is an institutional mechanism for the coordination and the application of knowledge to meet specific goals. Accordingly, job specifications are codified requirements – imperfect as they may be – of the repertoire of skills that the labour force is expected to possess and use in order to carry out successfully particular work tasks. By the same token at

higher levels of aggregation the employment structure of a sector is a blueprint of knowledge use embedded in specific occupations – or vectors of skill-task co-occurrences.

3. Data sources and methods

The empirical analysis is based on the Occupational Information Network (O*NET) electronic database of the U.S. Department of Labour (DOL). Data are collected using a classification system that organizes job titles into 1,102 occupations and collects information on their characteristics (National Research Council, 2010). We use information concerning physical and cognitive abilities that is occupation-specific and is provided by trained occupational analysts, job incumbents and occupational experts. The current taxonomy encompasses information on two broad categories, basic skills (e.g. reading, writing and listening) and cross-functional skills (e.g. problem-solving, technical maintenance, social skills, resource management skills, etc). O*NET are matched with employment data (source: US Bureau of Labor Statistics) by means of the Standard Occupational Classification (SOC). Our database is built by merging employment statistics on 285 sectors (4-digit NAICS) with the corresponding occupational information on skills contained in O*NET. Our observations are sector-specific vectors of skill scores for the period 2002-2012.

Our empirical strategy is based on the Method of Reflections of Hidalgo and Hausmann (2009, 2011). In particular, we create bipartite networks of sectors and skills whereby a connection between a sector and a skill signifies that the former utilizes the latter beyond a specific threshold, which Hidalgo and Hausmann label Revealed Comparative Advantage (RCA). Accordingly, a sector that exhibits higher diversification (i.e. its workforce uses more skills) is 'more complex' than a sector that uses less skills. Likewise, skills that are employed by less (more) sectors are more specialized (ubiquitous). Following the method of reflections we then calculate various measures of skill complexity such as: average 'ubiquity' of a skill (i.e. average number of sectors using that skill) and average degree of diversification of sectors (i.e. number of skills used above the RCA threshold by a sector). These measures offer a compact yet revealing indication of the complexity underlying the organization of a sector.

4. Preliminary results

We construct a diversification-ubiquity space to map the relative position of each sector in terms of complexity. Our preliminary finding reveals a strongly negative relation between

these two measures. This suggests that diversified sectors use exclusive skills: put otherwise, there exists some set of basic or standard skills, common to most of the sectors, and other skills more specialized that only diversified sectors use. The partitioning of this space in four blocks (corresponding to quadrants) containing different combinations of diversified or non-diversified sectors that use standard or exclusive skills allows a much richer articulation of sectoral types. To illustrate, we find that Basic (e.g. Mining, Agriculture) and Manufacturing industries tend to employ non-diversified sets of standard skills, thus exhibiting a relatively low level of complexity. On the other hand, FIRE and KIBS sectors use a more diversified set of exclusive skills: contrary to the literature that portrays KIBS as a homogeneous block, we observe greater variability in the knowledge composition of these sectors.

Using a novel methodology and highly original data we expect this paper to yield fresh insights into industry classifications and to afford the opportunity of assessing statistical associations between structural properties of the sector-networks and standard indicators of performance such as labour productivity.

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