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Innovation over the industry life-cycle: Evidence from EU manufacturing☆

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ABSTRACT

Empirical research has revealed some regularities regarding the innovation that takes place over the industry life-cycle. First, innovation is high when an industry is young and low when the industry matures, and second, product innovation decreases with industry maturity, while process innovation increases. The implications of these regularities are profound, but evidence is to date largely case based and it is hard to generalize and draw policy conclusions. We use a flexible measure of maturity and a novel modeling approach to investigate innovation patterns for 21 European manufacturing industries. Our results strongly support both assertions and lend support to life-cycle based R&D-policy.

1. Introduction

Modern growth theory suggests there is a strong link between R&D and economic growth.[1] The relationship has been established empirically in many ways and at many levels by relating R&D to country, industry and firm performance.[2]

Many of the conclusions drawn about the role of innovation on economic growth, however, ignore the influence of the industry life-cycle. Innovation is modeled as a stable and static process, where innovation inputs are assumed to create

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[1] See Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1998, 2005), and Jones (2005).

[2] See, for instance, Coe and Helpman (1995) and Coe et al. (1997) for country level studies, and Keller (2002), Scarpetta and Tressel (2002), Griffith et al. (2004), and Cameron et al. (2005) for industry-level studies.

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intermediate outputs and in the end economic growth in much the same way over time, heterogeneous countries, industries and/or firms.[3] Industry life-cycle theory, however, would argue that *who* innovates and *what* innovative activity is undertaken is closely linked to the *phase* of the industry life-cycle. Therefore the innovation process itself evolves systematically over the life-cycle.

With this paper we aim to enhance our understanding of the nature and impacts of innovation over the life-cycle of industries. Our analysis is organized around two assertions or 'stylized' relationships in the industry life-cycle literature (Klepper, 1996, 1997): (i) innovation is high when an industry is young and decreases as the industry matures, and (ii) product innovations are expected to decrease with industry maturity, while process innovations are expected to increase with industry maturity. The paper concludes with the examination of the consequences of possible R&D misallocation.

Taking an industry life-cycle approach to innovation has important policy implications. In particular, a life-cycle perspective on R&D policies seems to be in order. Our findings suggest that often advocated policy approaches work very differently in young and mature industries. If the goal is to stimulate technical change, then policy makers should be aware of the composition of economic activity over the life-cycle stages. For instance, if most of the economic activity is concentrated in young industries, our results suggest that a policy of generic R&D support will create most technical change. In addition, the government is unlikely to be able to identify and target future industry leaders in a young and dynamic industry that has not yet established a dominant design. If, in contrast, a large mature sector exists, then generic measures might fail to create technical change. And in that case, a policy that targets industry leaders is more likely to generate the desired outcome.

Our findings call for policy makers to carefully consider the stages in which they find their industries, their distance to the global technology frontier as well as the policy targets they set. Our results suggest that R&D policy in Europe should not be a one-size-fits-all, much less should emerging economies, like India and China, follow the advanced countries' recipes.[4] When the aim is to close the gap to productivity leaders in a mature industry, the best policy is very different from one that aims to increase technical change at the frontier. Carefully matching the aims of policy to the life-cycle stage of countries' industries is therefore called for.

In this paper we aim to build on that idea and investigate the dynamics of innovation over the life-cycle in a industry-level database for a panel of EU countries employing a novel empirical methodology. Our contribution is twofold. First, we introduce a flexible measure to classify industries into different life-cycle stages. Second, we propose a novel modeling approach, which allows to disentangle between product and process innovation, to empirically investigate innovation activity over the industry life-cycle on a comprehensive database of 21 European manufacturing industries.

The rest of the paper is organized as follows. In Section 2, we develop the intuition underlying the assertions (the aggregate implications of stylized facts established in the industrial organization literature) to be tested from the industry life-cycle literature and position our paper in the literature. In Section 3, we first discuss our data and classify the industries of our sample by their life-cycle stage and then present the stochastic frontier framework and estimate efficiency and technical change. In Section 4, we then present the empirical evidence on the assertions developed in Section 2. Finally, in Section 5, we conclude.

2. The industry life-cycle and R&D

The innovation process evolves and changes over the life-cycle at the product, the firm and the industry level.[5] This is because the underlying knowledge conditions vary systematically over the industry life-cycle, giving rise to two distinct technological regimes (Winter, 1984; Agarwal and Audretsch, 2001): an 'entrepreneurial' regime, which takes place at early stages of life-cycle, where innovation comes from knowledge that is not of routine nature and is favorable to innovative entry. In this formative stage, entrants are vying for the dominant product design thus focusing their efforts on product innovation. While the probability of success is low, if successful this brings subsequent high rates of growth. The other, 'routinized' regime, takes place at mature and declining stages of the life-cycle. Here innovation comes from knowledge that is more of a routine nature (e.g., optimizing production processes and supply chains) and less about (radical) innovative activity. The focus shifts to process innovation. In this mature stage, the opportunities for setting product standards through

[3] Innovation makes production a dynamic process that is changing over time as innovations are introduced, but the relation between innovation inputs and output is typically parameterized and assumed stable and uniform across time and units of observation to identify key parameters.

[4] Along similar lines, the study of Acemoglu et al. (2006) makes innovation policy contingent on the distance to the technology frontier and distinguishes between investment-based and innovation-based strategies over the course of development of an economy. Relatively backward economies can grow with an investment-based strategy, whereas countries nearer the frontier grow more based on innovation activities; an idea that relates to the Schumpeterian paradigm, which envisions economic growth through endogenous introduction of new products and process and firms (countries) should perform these introductions and go through certain phases (creative destruction) in order growth effects to be realized. The importance of dominant life-cycle stage of an economy and its role to growth is also stressed by Audretsch and Sanders (2011).

[5] The notion of industry life-cycle dates back to Vernon (1966) and was crafted into a comprehensive theoretical framework by Utterback and Suarez (1993) and Klepper (1996). This literature has explored both the theoretical implications and empirical regularities of the association between industry life-cycle phase and innovation. According to the industry life-cycle literature, as a new industry matures, prices fall and quantities rise, causing sales to typically rise before leveling off. Also, over the life-cycle the number of the firms initially rises and then drops causing average firm size to rise as the industry matures (Agarwal, 1998; Filson, 2001, 2002). These changes have been linked and attributed to technological innovations that occur at the industry level, such as the development of a dominant design (Jovanovic and MacDonald, 1994; Klepper, 1996). For further theoretical discussions on the association between industry phase and firm innovation, see Henderson and Clark (1990) and Tushman and O'Reilly (1997).