



# The dynamics of national innovation systems: A panel cointegration analysis of the coevolution between innovative capability and absorptive capacity

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## ABSTRACT

This paper investigates the idea that the dynamics of national innovation systems is driven by the coevolution of two main dimensions: innovative capability and absorptive capacity. The empirical analysis employs a broad set of indicators measuring national innovative capabilities and absorptive capacity for a panel of 87 countries in the period 1980–2007, and makes use of panel cointegration analysis to investigate long-run relationships and coevolution patterns among these variables. The results indicate that the dynamics of national systems of innovation is driven by the coevolution of three innovative capability variables (innovative input, scientific output and technological output), on the one hand, and three absorptive capacity factors (infrastructures, international trade and human capital), on the other. This general result does however differ and take specific patterns in national systems characterized by different levels of development.

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## 1. Introduction

The study of national innovation systems (NIS) has attracted considerable attention in the last two decades (Lundvall, 2007). While a substantial amount of research has been devoted to the investigation of cross-country differences in technological capabilities and the related institutional and policy framework, much less attention has so far been given to the analysis of the *dynamics* of national systems over time.

This is unfortunate, since evolution and change represent indeed key aspects of Schumpeterian research, which did in fact constitute some of the crucial motivations for the original development of the NIS approach. The lack of focus on dynamic aspects is partly explained by the non-availability of time series data for a sufficiently long period of time, and partly by the analytical and methodological difficulties that are faced when it comes to model and empirically analyze the dynamics of complex evolving systems (Foster, 1991).

The Schumpeterian literature on innovation and economic growth does however provide important insights and key building

blocks for developing an analytically stronger framework to study NIS dynamics. First, idea-based new growth models point out the important role of national innovation capability for the growth of the economic system (Romer, 1990; Furman et al., 2002). Secondly, technology-gap models highlight the important role played by countries' absorptive capacity for imitation-based catching up, and show the large set of factors that contribute to define a country's absorptive capacity (Abramovitz, 1986; Verspagen, 1991; Godinho et al., 2006; Fagerberg and Srholec, 2008; Lee and Kim, 2009).

Most of the empirical literature on innovation and growth, though, has so far neglected the study of two important issues. The first is that, while a substantial amount of research has been devoted to the analysis of the impacts of innovation on economic growth, the investigation of the determinants and drivers of national innovative activities, has so far received only limited attention (Castellacci, 2011; Filippetti and Peyrache, 2011). Secondly, the applied literature on innovation and growth has typically focused on the cross-country comparative aspect ("why growth rates differ across countries") and often neglected the time series properties of the process of technological change and economic development. In short, the existing literature provides only limited insights on the drivers of national systems of innovation and the mechanisms that may explain their evolution and growth over time.

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Motivated by this important gap, this paper adopts a time series perspective and shifts the focus to the analysis of the drivers of national innovation systems over time. In a nutshell, the paper puts forward the idea that innovative capability and absorptive capacity are linked by a set of two-way dynamic relationships, and that their process of coevolution represents a key mechanism driving the growth of national systems in the long-run.

Our empirical analysis makes use of a broad set of indicators measuring national innovative capabilities and absorptive capacity for a panel of 87 countries in the period 1980–2007. The empirical methodology that we adopt is rooted in the panel cointegration approach, which represents a recent extension of the time series cointegration analysis of non-stationary variables to the panel data context (Breitung and Pesaran, 2008). The cointegration methodology has an inherent ability to uncover dynamic relationships among variables that coevolve over time, and we therefore argue that it constitutes a natural platform for investigating the long-run dynamics of national systems of innovation.

The empirical results indicate that innovative capability and absorptive capacity variables are indeed linked by a set of long-term structural relationships over the period 1980–2007. Specifically, the dynamics of national systems of innovation is driven by the coevolution of two sets of factors: innovative input, scientific output and technological output, on the one hand, and infrastructures, international trade and human capital, on the other. Further, both of these dimensions coevolve with the growth of income per capita. However, we also find that these general results differ across country groups and take specific patterns in national systems characterized by different levels of development.

The paper is organized as follows. Section 2 provides a brief review of the literature, Section 3 presents the theoretical framework and hypotheses, Section 4 points out the data and indicators, Section 5 introduces the econometric method, Sections 6 and 7 discuss the empirical results, and Section 8 highlights the main conclusions of the work.

## 2. Literature review

National innovation systems (NIS) are key drivers of economic growth and competitiveness. The study of NIS focuses on the main components of the system, such as private firms and public organizations, and investigates their mutual interactions as well as their relationships with the social and institutional framework in which the system is embedded (Lundvall, 2007).

The study of the *dynamics* and *evolution* of national systems provided one of the original motivations for the development of this approach. However, the focus on long-run dynamics and historical transformations was mainly developed in a branch of qualitative and historical case studies research (Freeman, 1987; Nelson, 1993; Edquist and Hommen, 2008; Lundvall et al., 2009). By contrast, quantitative and modelling oriented contributions in this field have not yet provided a consistent and fully-fledged analysis of the complex set of factors that drive the dynamics of national systems in the long-run. This is partly due to the lack of a strong analytical framework able to describe the dynamics of NIS as complex evolving systems, and, correspondingly, it is also related to the lack of quantitative empirical tools (data, indicators and methods) that would make it possible to carry out an empirical investigation of such a theory of complex innovation system dynamics.

Important branches of the literature on innovation and economic growth do however provide key theoretical insights and empirical results on some of the main factors that are relevant to describe the long-run evolution of a national innovation system and its relationships to economic performance.

The first is new growth theory, and in particular Romer's (1990) idea-based growth model. This seminal work points out that the

growth of a country's knowledge stock, its innovation dynamics, depends on a few key factors such as the size of its research sector as well as the productivity of the latter, which defines the extent to which innovation input and investments are turned into innovation output and economic performance. The concept of *innovative capability*, despite its highly stylized character, defines a first key dimension to study the evolution of NIS. Furman et al. (2002) define it as "the ability of a country to produce and commercialize a flow of innovative technology over the long term" (2002:899).<sup>1</sup>

Romer's (1990) model has been highly influential and has inspired the development of an entire class of idea-based new growth models. Nevertheless, empirical analyses of this type of model have mostly focused on the main prediction of its reduced form on the relationship between the size of the research sector and the country's economic performance, and have, by contrast, typically neglected the investigation of its structural form, and specifically of the determinants of a country's innovation dynamics and its transformations in the long-run (Castellacci, 2007).

Secondly, a large modelling and empirical literature has focused on the process of international knowledge diffusion and investigated the set of factors that affect the extent to which a national system is able to grow and catch up with the technological frontier by means of international learning and imitation activities. This approach was originally inspired by the work of economic historians such as Landes, Gerschenkron and Abramovitz, which, by focusing on historical case studies of the technological catch up process, pointed out that international knowledge diffusion is a complex and demanding process, and investigated the set of factors that are necessary for imitation-based technological development. This set of factors, in a nutshell, defines the *absorptive capacity* of a country.

According to Abramovitz (1986, 1994), absorptive capacity may refer to both techno-economic characteristics (*technological congruence*) such as "the resource availabilities, factor supplies, technological capabilities, market scales and consumer demands", as well as socio-institutional conditions (*social capability*) like "countries' level of education and technical competence, the commercial, industrial and financial institutions that bear on their abilities to finance and operate modern, large-scale business, and the political and social characteristics that influence the risks, the incentives and the personal rewards of economic activity" (Abramovitz, 1994:24).

Inspired by these original insights, theoretical models in the technology-gap (or distance-to-frontier) tradition have developed a more stylized notion of absorptive capacity, and often focused on human capital as the single most important factor shaping a country's capability to imitate and absorb foreign advanced technologies (Nelson and Phelps, 1966; Verspagen, 1991; Benhabib and Spiegel, 1994; Papageorgiou, 2002; Stokke, 2008).

On the other hand, empirical works in this tradition have typically followed a growth-regression econometric approach, and shown the large variety of factors, of both a techno-economic and socio-institutional nature, that affect convergence and divergence patterns in broad cross-country samples (e.g. Fagerberg and Verspagen, 2002; Fagerberg et al., 2007; Fagerberg and Srholec, 2008; Castellacci, 2008; Lee and Kim, 2009).<sup>2</sup> Most of this empirical research, however, has so far focused on the cross-country comparative aspect ("why growth rates differ") and mostly neglected

<sup>1</sup> Furman et al. (2002), more precisely, used the expression "national innovative capacity", instead of the term *innovative capability* that is adopted throughout this paper.

<sup>2</sup> See overview of this empirical literature in Fagerberg (1994) and Gong and Keller (2004).

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