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Industrial leadership in science-based industries: A co-evolution model

Francisco Fatas-Villafranca*, Gloria Jarne, Julio Sanchez-Choliz

University of Zaragoza, Department of Economic Analysis, Gran Via, 2, 50005 Zaragoza, Spain

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ABSTRACT

In this paper, we seek to analyse the role of national university systems in combination with technological and market factors as sources of industrial leadership and industry growth in science-based industries. We propose a model in which national university systems and their respective national firms and industries are considered as co-evolving. National firms compete on a worldwide level and they rely on the progress of science and the availability of scientists to innovate. As the global industry develops, firms try to mold their national university systems, but they achieve different degrees of success. Apart from highlighting the role of institutional responsiveness as a source of competitive advantage, our model points to the access to essential inputs for production, the technological and strategic characteristics of firms, the international diffusion of knowledge, and the initial distribution of market demand as key sources of leadership and industry growth. The international mobility of scientists seems to foster the emergence of industrial leadership shifts.

1. Introduction

The development of many high-technology industries has witnessed the emergence of strong leadership positions. Thus, for example, the rise of science-based industries in Germany and other countries of continental Europe at the end of the 19th century (Murmann, 2003), or the consolidation of the American technological leadership during the post-WWII era (Nelson and Wright, 1992) illustrate the relevance of industrial leadership in science-based industries. In more recent times, the rapid growth of the Asian NICs came about because these countries managed to master complex electronics-based technologies to the extent of catching up with and, later, forging ahead of previous industrial leaders in high-tech industries (Amsden, 2001).

These episodes present economic theory with serious challenges summarized in three important questions. The first question regards the need to clarify what the sources of industrial leadership in high-tech industries are. Recent contributions point to the co-evolution between universities and a number of institutional, technological and market factors as key mechanisms underlying leadership and industrial leadership shifts (Rosenberg and Nelson, 1994; Mowery and Sampat, 2005). However, despite the excellent empirical, historical and appreciative studies that support this idea, our theoretical understanding of the processes involved is still far from satisfactory (Mowery and Nelson, 1999).

* Corresponding author.
E-mail addresses: ffatas@unizar.es (F. Fatas-Villafranca), gjarne@unizar.es (G. Jarne), jsanchez@unizar.es (J. Sanchez-Choliz).

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Nomenclature

List of symbols

q_i	level of production of the i-firm/industry
k_i	capital stock of the i-firm/industry
c_i	firm i's unit cost
A_i	level of technology of the i-firm/industry
A^*	technological frontier
w_i	salary of scientists in nation i
r_i	firm i s R&D to sales ratio
u_i	university budget devoted to a relevant scientific discipline in nation i
y_i	number of scientists finishing their training at the i-national uni-system at any time
h_i	number of scientists working in the i-national industry
s_i	firm/industry i s market share
f_i	firm/industry i s capital productivity
n	number of firms/national industries
p	product price
t	time
γ_i	firm/industry i s R&D budget
ρ_i	firm/industry i s production costs per unit of capital
π_i	firm/industry i's profit rate per unit of capital
λ_i	national university system i s institutional responsiveness
α_i	firm/industry i s technological capabilities
β_i	firm/industry i s absorptive capacity
χ_i	firm/industry i s productivity of R&D
υ_i	share of new mobile scientists that join the i-national industry
δ	size of the global market potential
b	returns to scale parameter
a_x	heterogeneity degree regarding the x-factor (simulations)
x	factor that we study in each case (simulations)
ϕ_x	weight of the x-source of leadership (econometrics)
θ	propensity to invest
ε	sensitivity of mobile scientists to non-monetary factors
σ	level of rigidity in the international mobility of scientists

The second question concerns the need to go beyond the immediate factors – capital accumulation, human capital and technical change – that usually explain growth in contemporary models. The complex techno-institutional changes, which have made the science-based industrial transformations in Western Europe, the US or South-East Asia possible, overwhelm the explicative capacity of most theoretical models, in which institutions play an exogenous and minor role. Abramovitz (1952) pointed out this shortcoming more than fifty years ago, but it still remains an open issue today (North, 1990; Nelson, 2005).

The last question regards the theory of economic development. If we pose the challenge of development as a catch-up problem – very much in the spirit of Gerschenkron (1962) or Freeman (2004) – episodes as surprising as the strong rise of Japan during the 20th century or, more recently, the cases of Korea, Taiwan, Singapore or Brazil show how little we know about the role of supporting institutions in economic development. In this respect, Mazzoleni and Nelson (2007) have argued that, in order to catch up in the 21st century, developing nations may need to adapt certain institutions – domestic university systems and public research institutions – to generate more strength in the relevant fields of science and technology.[1] If this is so, for emergent nations to catch up will require a proper understanding of the subtle mechanisms of institutional change (Cimoli et al., 2006).

In this work, we take on the aforementioned challenges by proposing a co-evolution model of institutions and technology that should be able to shed new light on the sources of industrial leadership in high-tech industries. Furthermore, our proposed model assumes a major role for institutions in economic growth, and it fits with the conception of development as a catch-up problem.

In our model, heterogeneous for-profit firms, with distinct national identities, co-evolve with their respective national university systems. Firms compete on a worldwide level in a science-based industry, and they drive technological change

[1] Reasons for this adaptations include the stricter legal conditions established by the WTO, the increased protection of intellectual property rights in the TRIPS agreement, and the powerful contemporary expansion in many fields of application-oriented sciences.