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A history-friendly model of the successive changes in industrial leadership and the catch-up by latecomers

Fabio Landini[a,b,*], Keun Lee[c], Franco Malerba[b,d]

[a] LUISS University, School of European Political Economy, Italy
[b] Bocconi University, ICRIOS, Italy
[c] Seoul National University, Department of Economics, Republic of Korea
[d] Bocconi University, Department of Management and Technology, Italy

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ABSTRACT

Successive changes in industrial leadership between both firms and countries (described here as catch-up cycles) have been common in several sectors. This article develops a history-friendly model to explore the role played by technological conditions in the emergence of such leadership changes. The model is inspired by two cases where the emergence of disruptively novel technology played an important role: mobile phones and semiconductors. In the baseline setting the model is able to generate the benchmark case of three cycles with two leadership changes. In particular, the simulation analysis reveals that: (a) the more disruptive the new technology and the lower the incumbents' capabilities, the greater the shake-up of market shares between incumbents and latecomers; (b) leadership change is more likely to occur when it coincides with certain responses by the actors to the technological disruption, such as a high lock-in behaviour on the part of incumbents; and (c) a technology-driven change of industrial leadership is more likely to occur in the presence of increasing returns to technological investments. The counterfactual experiments show that different catch-up dynamics can emerge depending on the magnitude of technological disruption, the degree of lock-ins, the shape of technological landscape, and incumbents' initial capabilities. In particular, four other types of catch-up cycle are generated – the aborted cycle, persistent leadership, return of the old leadership, and coexistence in leadership between latecomers and incumbents. Each of these cycles is identified with a specific historical case of catch-up.

1. Introduction

As noted by Schumpeter, one of the essential aspects of capitalism is creative destruction, often leading to changes in industrial leadership between firms both within and across countries. The extensive literature about this kind of change includes studies using differing levels of analysis. Some (*e.g.*, Tushman and Anderson, 1986; Christensen, 1997) concentrate on shifts in leadership at the level of firms within national economies – in those cases focusing on advanced industrial economies. Others, in contrast, while recognising the importance of leadership change at the firm level, subordinate that dimension beneath a primary interest in shifts of leadership at the level of national economies, as in the classic studies by Gerschenkron (1962) and Abramovitz (1986), as well as Mowery and Nelson (1999).

Building on those themes, a large literature now exists about the rise of industrial leadership in emerging economies in industries like mobile phones, shipbuilding, automobiles and steel. Again the levels of analysis vary widely. Some studies concentrate on the rise of individual firms (Kim, 1997; Lee and Lim, 2001; Amann and Cantwell, 2012), while others give primary attention to leadership shifts between national economies, but at the level of specific sectors (Malerba and Nelson, 2012).

A third perspective seeks to connect those different levels of analysis. A pioneer in this is Amsden (2001), whose examination of the rise of late-industrialising economies is deeply rooted in the analysis of firm-level behaviour. More recently, Lee (2013) explicitly integrates his primary focus on country-level economic growth with analysis at the level of both sectors and firms. This article also adopts that perspective. Like most of the other articles in this Special Issue, it is primarily concerned with shifts in industrial leadership between firms located in different national economies, mainly involving shifts between advanced and emerging (latecomer) economies; but this analysis is rooted in the micro-level behaviour of individual firms and the characteristics of specific sectors.

* Corresponding author at: LUISS University, School of European Political Economy, Italy.
E-mail address: flandini@luiss.it (F. Landini).

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One feature of such leadership change is that, within a considerable number of industries, change seems to have occurred repeatedly. Christensen (1997), for example, note this pattern in the history of several industries in the US, most strikingly in the hard disk drive industry where four changes in leadership occurred in only about three or four decades. This occurrence of successive inter-firm leadership changes has also been observed in cases that have simultaneously involved shifts in leadership from advanced to latecomer economies. This is evident, for example, in two cases that were especially important in inspiring the development of this article: in mobile phones where leadership shifted from the US to Europe, and then from Europe to Korea and (partly) back again to the US (Giachetti and Marchi, 2016), and in memory chips where it moved from the US to Japan and from Japan to Korea (Shin, 2016). However, not much has been written specifically about these paths of successive change in industrial leadership across countries within particular industries. This article expressly aims at filling that gap.

We start by following Lee and Malerba (2016) in using the term 'catch-up cycles' to refer to successive changes in industrial leadership with each cycle consisting of entry, gradual rise, forging ahead and decline of a leader, followed by the rise of next leader with its own cycle. Then, influenced by the cases noted above and along with those examined in the other articles in this Special Issue, we ask the following question: under what conditions do catch-up cycles occur in industries and why do they often occur more than once in the same industry?

In addressing this question, we do not present new empirical observations. Instead we develop a formal model to explore the conditions within which catch-up cycles are more likely to emerge. In doing so, we draw on the case studies mentioned above. In particular, we note that the emergence of novel technologies (sometimes combined with government interventions and demand shocks) played an important role in opening opportunities for leadership change in all these cases, including the studies of leadership change within industries in the advanced economies (*e.g.* Tushman and Anderson, 1986; Christensen, 1997). This opportunity-opening role of technological discontinuities is therefore the main focus of the present article, following the argument of Perez and Soete (1988) that radical technological discontinuities often create 'windows of opportunity' for latecomer firms and economies. We extend that core idea further in two ways. First, we envisage that the 'size' of technology-driven windows of opportunity may vary, as reflected in the magnitude of the technological discontinuity, with corresponding variability in the consequent disruption to existing markets and capabilities. Second, we envisage that the extent to which leadership change depends not only on the size of the technological windows of opportunity, but also on how the incumbents and latecomers respond to the opening of the windows.

We elaborate on these and other detailed aspects of the model in Sections 2 and 3. However, we highlight here two of its more general features: (i) the scope of the questions it addresses, and (ii) several broad aspects of the approach we take.

The scope of our exploration overlaps with, but is nevertheless distinct from, several other strands of research concerned with late industrialisation and the underlying dynamics of technological change. At one level our study relates to previous work in this area by economic historians, as in the pioneering contributions of Gerschenkron (1962) and Abramovitz (1986) as well as Chang (2002). However, our exploration of catch-up cycles is more narrowly focused than such broad-ranging studies. It is centred specifically on shifts in industrial leadership – in terms of latecomers overtaking the incumbents in terms of global market shares, or at least closing the gap in market shares to the extent that they acquire similar shares to the global market leaders.

At another level, the focus on shifts in industrial leadership means that our model-based exploration differs from other related studies that also focus on how innovation and technological change influence shifts of industrial activity to late industrialising economies. This merits clarification in three areas.

First, in his analysis of the product life cycle, Vernon (1966) argues that the maturation of product technologies after the initial innovation in the US contributes to shifting the geographical location of those productions, first to other advanced economies and then later to developing economies. However, Vernon concentrates on the patterns of international investment that launch new lines of production in those follower economies, and he is not concerned with questions about whether and how the global geography of leadership in those industries might subsequently also shift. Moreover, his discussion is entirely about how the location of production is shifted via foreign direct investments by multinational corporations based in advanced economies. Perhaps not surprisingly, there are no questions about whether this incumbent-driven process of international investment might somehow evolve into change in industrial leadership involving not only production but also R&D and brands.

Similarly, although we draw directly on Perez and Soete's (1988) insights about technological windows of opportunity, we use their idea to address a different question. They are primarily concerned with entry into new industries by firms in late industrialising economies, and they focus on ways in which some of the entry barriers might be lower during phases of radical technological discontinuity. In contrast, our focus is on events occurring two, three or more decades after initial entry – on questions about whether technological discontinuities provide opportunities at that later stage for latecomers to catch up or even forge ahead into globally leading positions in the industry, overtaking the incumbents.

The same distinction between industry entry and subsequent change in industrial leadership applies with respect to the connection between this study and the literature on 'product space' (Hidalgo et al., 2007). As with our study, this strand of work addresses questions about technology and late industrialisation, arguing that the structure of capability distances in the product space in which firms are embedded shapes the rate and direction of change in the structure of industrial production and exports. However, this argument is again about start-up steps in entering new-to-the-economy lines of business, and no questions are raised about whether or how global changes in industrial leadership might subsequently follow on.

While concentrating on the incidence of leadership change within catch-up cycles in industries, we focus on catching-up by firms in latecomer countries. However, our model is quite general and it can be used to explain catching-up by firms in an advanced country that starts from a position of late entry into a specific industry compared to firms of another advanced country.

The model is developed along the lines of the evolutionary models of Nelson and Winter (1982) and the history-friendly tradition (Malerba et al., 1999, 2016). History-friendly models are evolutionary models in which aggregate behaviours emerge out of the repeated interaction among agents. These models were used to examine the evolution of several industries, such as computers, semiconductors, pharmaceuticals, and memory chips (for a review, see Garavaglia, 2010). In those cases, a specific industry is the object of analysis and the actors and mechanisms that characterize that single industry are explicitly modelled. In this article we adopt a slightly different approach. Our model is not restricted to the specifics of one industry. Although it was inspired by the cases of mobile phones and memory chips, we build a simulation model that is general enough to capture the gist of catch-up cycles in more than one industry. We do this in stages. Initially, the model focuses on the commonalities that characterize the standard catch-up cycles

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