Research Policy 46 (2017) 338–351

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Catch-up cycles and changes in industrial leadership:Windows of opportunity and responses of firms and countries in the evolution of sectoral systems☆

Keun Lee[a,*], Franco Malerba[b]

[a] Seoul National University, Seoul, Republic of Korea
[b] ICRIOS, Bocconi University, Milan, Italy

ARTICLE INFO

Article history:
Received 15 April 2014
Received in revised form 20 May 2015
Accepted 1 June 2016
Available online 10 October 2016

Keywords:
Industrial leadership
Catch-up
Sectoral systems
Windows of opportunity
Leapfrogging strategies

ABSTRACT

This study proposes a framework that aims to explain why successive changes in industry leadership (called also the catch-up cycle) occur over time in a sector. In catch-up cycles, latecomer firms and countries emerge as international leaders, whereas incumbents lose their previous positions. New leaders are then dethroned by newcomers. To identify factors at the base of catch-up cycles, this article adopts a sectoral system framework and identifies windows of opportunity that may emerge during the long-run evolution of an industry. This study proposes three windows related to the specific dimensions of a sectoral system. One dimension is related to changes in knowledge and technology. The second dimension pertains to changes in demand, and the third includes changes in institutions and public policy. The combination of the opening of a window (technological, demand, or institutional/policy) and the responses of firms and other components of the sectoral system of the latecomer and incumbent countries determines changes in industrial leadership and catch-up. Sectors differ according to the type of windows that may open and the responses of firms and other components of systems. Empirical evidence of catch-up cycles is presented from six sectors, namely mobile phones, cameras, semiconductors, steel, mid-sized jets, and wines.

1. Introduction

Changes in industrial leadership from an incumbent country to a latecomer are often observed in several industries, such as the steel industry. In the first half of the 20th century, US firms dominated the production of steel, but they were soon replaced by Japanese companies that emerged in the 1970s. However, Japanese firms have been challenged by Korean firms since the 1980s (Yonekura, 1994; Lee and Ki, 2017). The successive shifts in leadership in the automobile industry are evident in the shift of leadership from Germany to the US, the US to Japan, and possibly to Korea or China. In the mobile phone industry, Motorola invented the mobile phone and is considered the pioneer in the industry. However, Nokia gained control of the market given the emergence of mobile phones based on different standards, namely, GSM digital technologies. The era of smartphones emerged later and enabled Samsung and Apple to topple Nokia (Giachetti, 2013; Giachetti and Marchi, 2010).

These phenomena of successive changes in industrial leadership are called "catch-up cycles". Many industries have witnessed several changes in industry leadership and successive catch-up cycles. In these cases, the incumbent fails to maintain its superiority in technology, production, and marketing. Such a failure allows a latecomer to catch up with the incumbent. Later on, the latecomer that has gained leadership will relinquish its position to a new latecomer. This study attempts to explain these phenomena by answering the following questions. How is the catch-up cycle characterized? How does it occur? How do latecomers catch up with incumbents and acquire industrial leadership?

A framework that answers these questions should include determinants of successive catch-up cycles that go beyond the product life cycle theory (Posner, 1961; Vernon, 1966); such a framework should focus on the movement of innovation and production from

☆ Previous versions of this paper were presented at the Bocconi University Milan Workshop (2012), the Seoul Workshop (2013), and the 2013 Globelics Conference. This work was supported by a joint research program between Bocconi University and Seoul National University under the framework of an international cooperation program managed by the National Research Foundation of Korea (2012K2A1A2031787) and the Catch-up Program coordinated by Richard Nelson. We also thank an anonymous referee, and Martin Bell for his thoughtful guidance throughout the revision of the paper.

* Corresponding author.
E-mail addresses: kenneth@snu.ac.kr (K. Lee), franco.malerba@unibocconi.it (F. Malerba).

http://dx.doi.org/10.1016/j.respol.2016.09.006
0048-7333/

advanced to emerging countries. The framework should start from well-established explanations of catch-up that are centered on initial conditions (Fagerberg, 1988; Fagerberg et al., 2010), macro variables (e.g., labour costs and exchange rates) (see Katz, 1995), firm capabilities (Bell and Pavitt, 1993; Kim, 1997; Lall, 2001), and national innovation systems (Freeman, 1987; Lundvall, 1992; Nelson, 1993). These studies provide comprehensive explanations on the catch-up phenomenon. However, the conceptual framework involved in examining successive catch-ups must go beyond these explanations because leadership frequently changes from one country to another and the features and determinants of catch-up differ across sectors.

We need to clarify a number of issues before we proceed with the article. First, we refer to "catch- up" as the process of closing the gap in global market shares between firms in leading countries and firms in latecomer countries. Catching up does not mean cloning. Firms and countries conduct activities differently, thereby leading to the development of an indigenous process of learning and capability building. The process of catching up firms and countries often diverges from the practices of pioneering firms and countries that serve as industry models. The organizational, managerial, and institutional aspects of productive practices are often the most difficult to replicate and must be adapted to indigenous conditions, norms, and values. Firms and countries that are catching up may perform activities that are different from those adopted by the leaders as a result of a local process of learning and capability building. The countries involved in this process may follow different trajectories of technological and product advancements and position themselves in varying ways along the catching up ladder (Katz, 1995; Bell and Pavitt, 1993; Kim, 1997; Malerba and Nelson, 2011; Lee, 2013).

Second, we define "leadership" according to the definition proposed by Mowery and Nelson (1999), who broadly used the term "industrial leadership." These authors referred to industrial leadership as possessing advantages in world markets as a result of being ahead of one's competitors in terms of product or process technologies or production and marketing practices and strategies (Mowery and Nelson, 1999; p. 2). The present article refers to "leadership" as the position of a country that has achieved a commanding position in a specific industry based on its share in the global market and its superiority in technology, production, or marketing. Changes in industrial leadership involve innovative behavior of the catching up country. However, the global market share of a country in an industry is difficult to measure because this often refers to the leading firms in a country. Another challenging task is comparing the dynamics of global market shares of countries over a long period because the boundaries and characteristics of the industry may change drastically over time. Given these observations, we maintain our definition of industrial leadership in terms of domination of global markets in an industry. Such a domination is assessed through a combination of measured market shares and evaluation of industry experts.

Third, we focus on the sectoral leadership of a specific country. We claim, as will be discussed later in the article, that firms share a common context related to the national or local networks, infrastructure, university system, human capital, financial organization, and institutions and policies of the country. Given this reason, firms from the same countries often emerge as leaders in a sector. Depending on the size and characteristics of a sector, this leadership may imply a large or small number of firms. For example, the wine sector consists of a large number of firms in most countries, whereas the camera industry in Japan consists of a small number of firms that changed over time from two to five or six firms. The sector may even consist of a single firm, such as steel in Korea or mid-sized aircraft in Brazil.

Finally, we focus on catching up by "latecomers"/"emerging countries" (we use these two terms interchangeably). We explain why a firm from a latecomer country could gain international leadership and eventually lose its leadership position to firms from another latecomer country. Our proposed conceptual framework is quite general and can also be applied to the catch-up of latecomer firms in a specific industry of a developed country.

This Special Issue includes an analysis of a variety of sectors from high-tech to traditional ones: mid-sized aircraft (Vértesy, 2017), mobile phones (Giachetti and Marchi, 2017), wine (Morrison and Rabellotti, 2017), semiconductor memories (Shin, 2017), cameras (Kang and Song, 2017), and steel (Lee and Ki, 2017). While in most of them the shift of leadership is in favour of Asian countries, for two (mid-size aircraft and wine) the leadership moves to Latin America or returns to Europe. In addition, the analysis of the wine sector allows us to shed light on the dynamics of natural resource-based sectors, which present peculiar features compared to the other sectors.

Our conceptual framework indicates successive catch-up cycles and changes in industrial leadership based on the notions of sectoral system and the evolution of this system. We examine industries as systems. According to Malerba (2002, 2004), the building blocks of a sectoral system consist of regimes of knowledge and technologies, demand conditions, actors and networks, and institutions. These elements interact in various ways. These interactions generate a variety of outcomes in innovative and market performance, growth, and industry structure and dynamics. Sectoral systems evolve and change over time. Some of these changes are incremental and build upon previous characteristics and features, whereas other changes are radical and represent discontinuities with the past.

We refer to these discontinuities in the dynamics of a sectoral system as "windows of opportunity." The concept of "windows of opportunity" was first used by Perez and Soete (1988) to refer to the role of the rise of new techno-economic paradigms in the leapfrogging of latecomers who take advantage of a new paradigm and overtake incumbents. We expand the notion of windows of opportunity by linking them to the building blocks of a sectoral system. We then identify three types of window, namely, technological, demand, and institutional. "Technological windows" could explain the advances of Korean producers in consumer electronics in the digital era against the incumbent Japanese who were leaders during the analog era (Lee et al., 2005). A "demand window" refers to a new type of demand, a major shake-up in local demand or a business cycle. A major increase in demand in China or a new set of consumers (e.g., demand for low cost cars in India) may enable new firms from a latecomer country to enter the market. A business cycle creates a situation, wherein the incumbents encounter difficulty during economic downturns, whereas latecomers enjoy costs of entry that are lower than those in normal periods (Mathews, 2005). An "institutional/public policy window" can be opened through public intervention in the industry or through drastic changes in institutional conditions. For example, public policy windows are prominent in several catch-up cases, such as in high-tech industries in Korea and Taiwan (Lee and Lim, 2001; Mathews, 2002), the telecommunications industry in China (Lee et al., 2012), and the pharmaceutical industry in India (Guennif and Ramani, 2012).

This study utilizes the concepts of "windows of opportunity" and of "response" of firms and other components of the sectoral system of a country to the opening of a window of opportunity in an industry. Firms in latecomer countries may take advantage of these windows because of their responses. These responses depend on their learning processes, level of capabilities, organization, and strategies. In addition, the responses of the other components of the sectoral system in a specific country may play a major role in the catching up because of the diverse types and levels of networks,

education and university system, financial organizations, and public policy. All firms in an industry in an emerging/latecomer country share the same system responses. However, some firms may benefit more from the responses of the sectoral system and move to a global leadership position.

By contrast, current leaders from a certain country may lag behind because of the lack of effective responses attributed to "incumbent traps" (Chandy and Tellis, 2000) and system misalignments or inadequacies in the new window. Firm leaders tend to become complacent and entrenched with their current success. They do not pay attention to new technologies, disruptive innovations, new types of demand, or newly growing markets. Leadership changes occur even without apparent "mistakes" being made by incumbents. Moreover, the system in which the current leaders are embedded may not be able to change or adapt to the new window, which could impede or negatively affect the incumbents.

In summary, the evolution of a sectoral system may open several "windows" that prompt different "responses" from latecomers and incumbents, thereby resulting in changes in industrial leadership. New leaders from an emerging country gain global leadership, whereas incumbents experience a decline in leadership positions. The emergence of another window may allow new leaders from a new latecomer country to dominate and displace current leaders. This situation may occur several times. Our theory suggests that diverse combinations of windows of opportunity and responses from incumbents and latecomers determine the pattern of successive catch-ups that will most likely emerge in a sector. This study mainly suggests that catch-up cycles may significantly differ across sectors in terms of the characteristics, frequency, and actors (firms/countries) involved because of the possible differences in the characteristics of a sectoral system and its evolution.

This study adopts the approach of "appreciative theorising" (Nelson and Winter, 1982; p. 46) and aims to provide a "causal explanation of observed patterns" of leadership changes across sectors. A more "formal" companion paper is Landini et al. (2017), which developes a model of catch-up cycles and of the key mechanisms involved in leadership changes, through simulation modelling. This model is briefly discussed in Section 4.

The article is organized as follows. Section 2 describes the stages of catch-up cycles. Section 3 proposes and discusses the theoretical framework used for the analysis of catch-up phenomenon. Section 4 reviews the formal model of catch-up cycle. Section 5 provides evidence on the catch-up cycles in six sectors, namely, mobile phones, cameras, semiconductors, steel, mid-sized jets, and wine. Section 6 summarises the conclusions and discusses the policy issues raised.

2. The phenomenon of successive catch-up cycles and changes in industrial leadership

This section characterizes the phenomenon of successive catch-ups. We start by broadly representing the rise of firms in country A to global leadership. If we represent these dynamics with global market shares on the vertical axis and time on the horizontal one, we can characterize the emergence of global leadership by the firms of country A based on the rise of market shares of these firms over time from A_0 to A_1 (Fig. 1).

We then introduce a "standard" catch-up cycle, wherein latecomer country B enters the scene and starts production at time B_0. The first stage is the "entry" stage, in which the latecomer attempts to enter an industry and overcome its disadvantages by utilizing macro factors, such as low factor costs. The second stage is "gradual" catching-up in terms of market shares, which are usually based on cost advantages, investments, learning, and gradual accumulation of capabilities. The third stage is that of "forging ahead", which is based on the opening of windows of opportunity and effective responses to those windows. In this stage, the latecomer country has achieved the position of leadership at time B_1. This stage is often associated with the decline of incumbent A (see Fig. 2).

The fourth and final stage of a standard catch-up cycle is the "falling behind" of new leader B, which tends to decline with the rise of new challenger C. Fig. 3 presents the full catch-up cycle including the four stages associated with country B.

If we consider that country C is challenged by new latecomer country D, which may gain the leadership at the expense of C, a series of catch-up cycles may occur. Countries B and C undergo a catch-up cycle, and each country gains and then loses industrial leadership.

This "standard" cycle has four variations. The first is the case of an "aborted" catch-up in which the catching-up effort fails to generate a consistent gradual catch-up and the stage of forging ahead. Companies stagnate somewhere in the stage of gradual catch-up, which then leads to gradual decline. Several latecomer countries fall into this category of aborted catch up. The critical barrier that prevents these countries from reaching the forging ahead stage is the inability to learn and generate upgrades in value-added products. Another barrier is the lack of an effective and articulated system that supports firms in their catching up, particularly at the time of arrival of new technologies or the opening of new markets (see Fig. 4). An example of this phenomenon is the software industry in Ireland, which started a catching up process with regard to the incumbent (US) but failed to reach a leadership position (Mani, 2013).

The second case is that of "persistent" leadership, in which the leader continues to stay on top and maintains its position for a long time. The leader both invests to cope with new technologies or demand conditions and is able to adapt to a drastically changing environment. This case is illustrated in Fig. 5, which shows the memory chip and camera industries in Korea and Japan, respectively (Shin, 2017; Kang and Song, 2017).

The third case is the "coexistence of the old and the new leaders," in which the latecomer country reaches a leadership position, but shares this position with the new leader (Fig. 6). Examples of this case are the automobile and wine industries (Morrison and Rabellotti, 2017). In the case of the latter, new leaders (US, Australia, South Africa, and Chile) share leadership with old leaders (France and Italy).

The fourth case is the "return of the old leadership", in which the incumbent that lost its leadership position to the newcomer returns to a position of prominence in the new cycle (Fig. 7). An example of this case is the wine industry of Italy during the first decade of the 2000s and the market position of the US in videogames in the second decade of 2000.

This article first focuses on the standard catch-up cycle. We briefly discuss the entry and gradual catching up stages. We then focus on forging ahead and change in industrial leadership, in which the latecomer country becomes dominant. The main focus of this study is the change from A_1 to B_1, in which leadership change pertains to a latecomer country.

Section 3 examines the factors that determine the stage of forging ahead and change in industrial leadership.

3. Theoretical framework of catch-up cycles in industries and changes in industrial leadership

3.1. Early studies on the life cycles of international product

Early studies on international product life cycle examined the entry of developing countries into new industries (Posner, 1961; Vernon, 1966). Product cycle theory argues that products undergo a

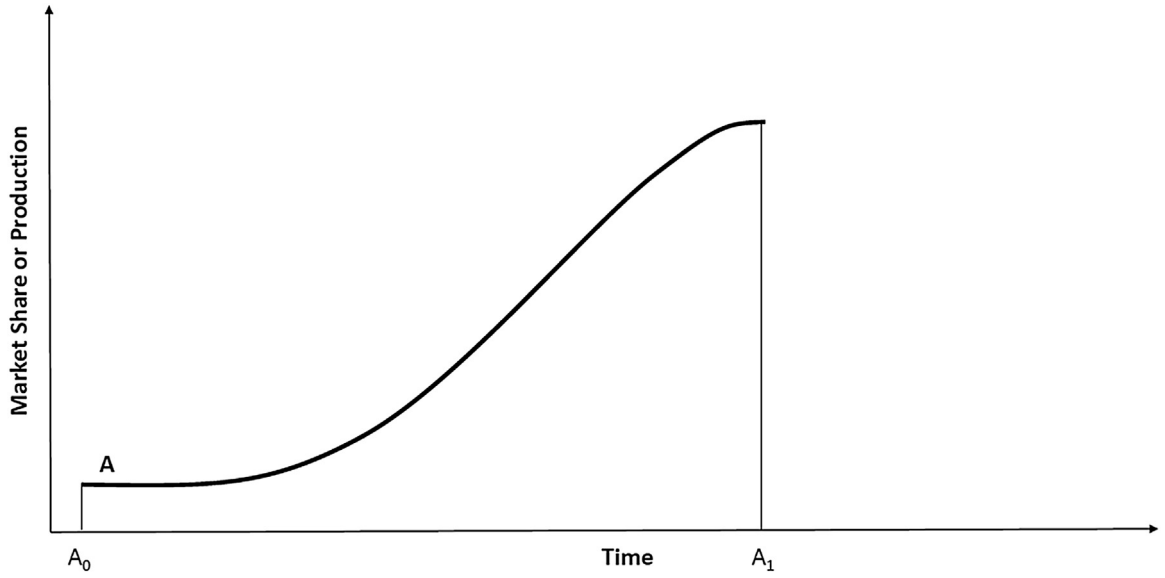

Fig. 1. Leading Country A.

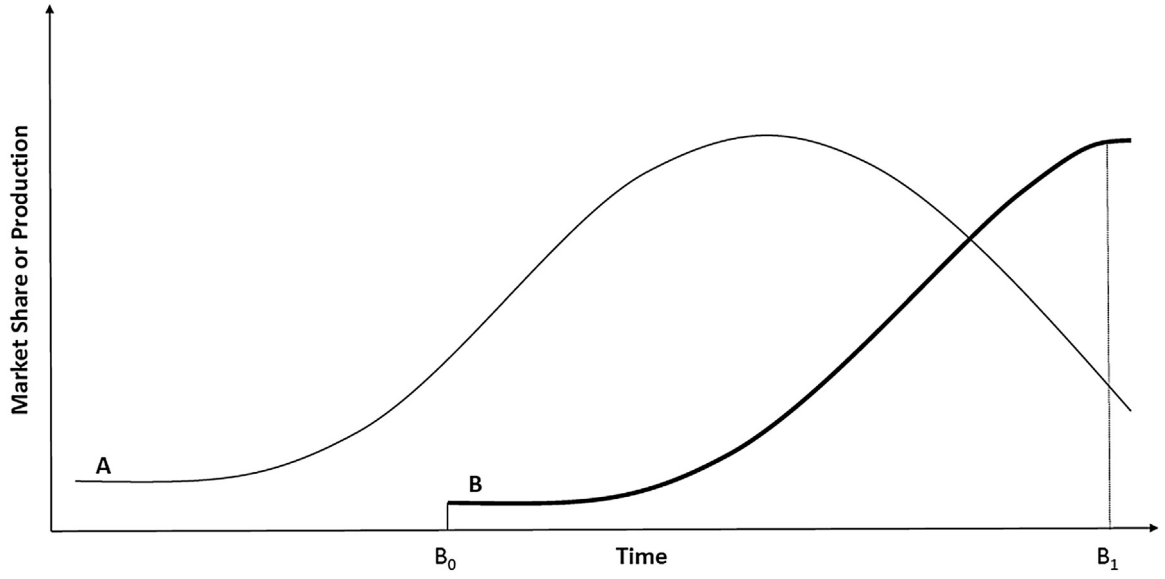

Fig. 2. Latecomer Country B.

life cycle or set of stages (introduction–maturity–standardization). The cost of production is a critical factor of comparative advantage, which explains the shift in production sites from developed to developing countries. Thus, the location of production of established goods is eventually moved from developed countries to developing countries. The costs of production, especially wage rates, in developing countries are cheaper than those in developed countries. Product cycle theory examines only the production cost differences. According to Mowery and Nelson (1999), this theory has basic weaknesses because it is applied to products rather than industries; this theory is also applied to a single "life cycle" of a given product or technology and to industries that do not generate multiple technologies in their historical development. The theory also focuses only on imitation and entry, which are merely the start of a long story that includes the later stages of forging ahead or leadership change. The theory does not attribute changes in industrial leadership to the interaction of industrial and institutional elements. In summary, the theory implicitly assumes that the leadership of an industry always remains in advanced countries, whereas the idea of catch-up cycles implies that not only the production sites but also the leadership position could move to developing countries.

3.2. Catch-up cycles in sectoral systems

We propose that a framework of sectoral systems with a dynamic perspective provides an improved starting point. This framework explains why latecomer countries enter an industry, gradually catch up, sometimes forge ahead, and eventually decline. The perspective of the sectoral system suggests that firms are a part of systems that comprise other actors and institutions (Malerba, 2002, 2004). Firms in industries learn and accumulate capabilities in systems that consist of knowledge and technologies of the sector, demand conditions in terms of users and consumers, and other actors (e.g., government, universities, suppliers, financial organizations, public research centers) and institutions (including public

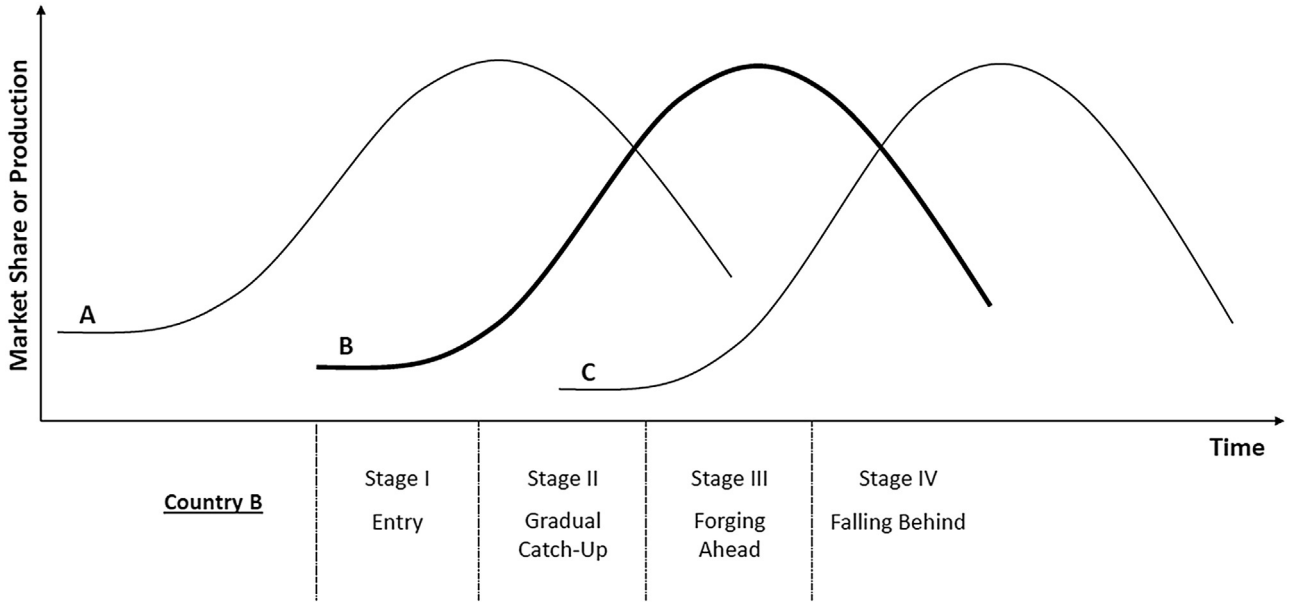

Fig. 3. Stages in Industry Catch-Up Cycle.

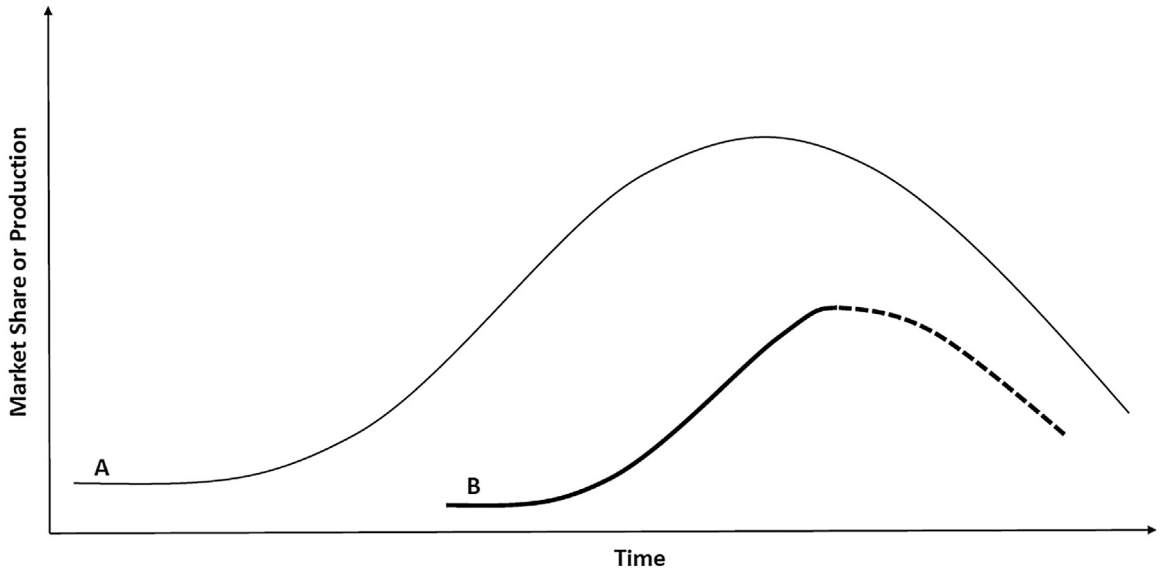

Fig. 4. Aborted Catch Up Cycle.

policies, IPRs, laws, culture). Firms and other actors in a sectoral system are interconnected. These firms are involved in the processes of competition, cooperation, innovation, or imitation. Sectoral systems evolve over time through co-evolutionary processes in their elements (Nelson, 1994; Malerba and Adams, 2013). This dynamic view of a sectoral system can be used to examine successive catch-ups. The framework of the sectoral system is applied in industries (Mowery and Nelson, 1999; Malerba, 2004) and developing and emerging economies (Malerba and Mani, 2009). The framework has been used to examine sectoral factors that affect the success or failure of latecomer countries in the catching-up process in a specific industry (Malerba and Nelson, 2011, 2012; Lee and Lim, 2001; Lee et al., 2005; Mu and Lee, 2005; Mani, 2005, 2007; Gu et al., 2009; Yu et al., 2016). However, these studies used the framework of the sectoral system to analyze cases of catch-up (or failure to catch-up) in individual industries. These studiies did not examine catch-up cycles using a long-term and multi-country comparative perspective.

3.3. Early stages of a catch-up cycle: entry and gradual catch-up

3.3.1. Entry and initial growth

The entry stage could be associated with explanations related to "initial conditions," "macro factors," and "sectoral and national systems factors." Initial conditions may link the growth of emerging countries to the presence of factor endowments, natural resources, culture, the extent of inequality, historical legacies, legal institutions, industrial structure, and entrepreneurship (Fagerberg, 1988; Fagerberg et al., 2007, 2010). These conditions may lead firms in emerging countries to a phase of entry and initial growth. Similarly, macro variables, such as low labour costs, could be a major source of entry and initial growth of countries. Some development

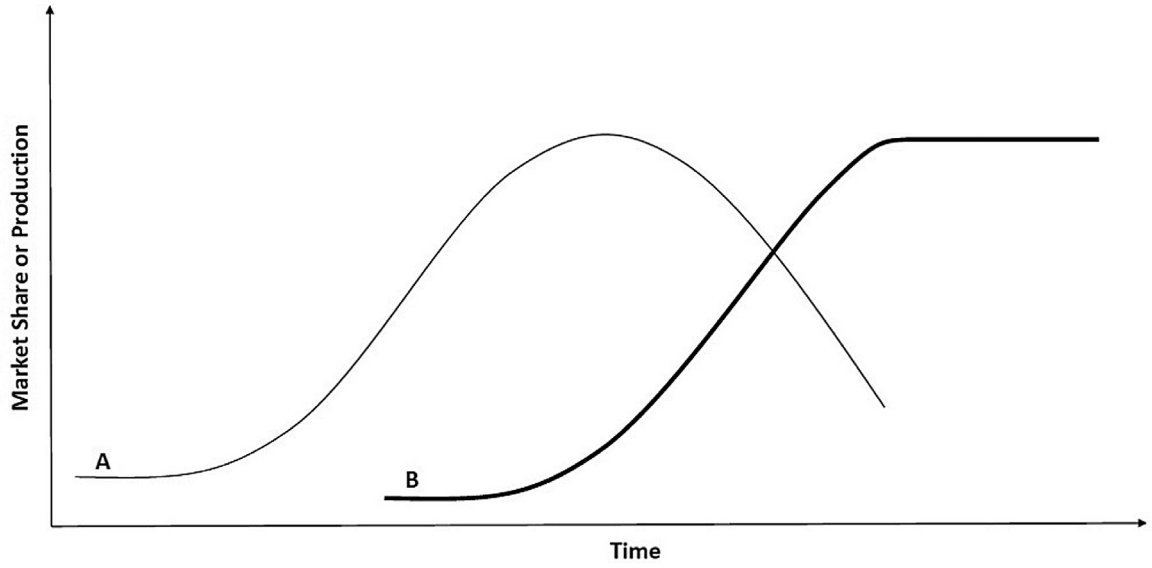

Fig. 5. Persistency of Leadership.

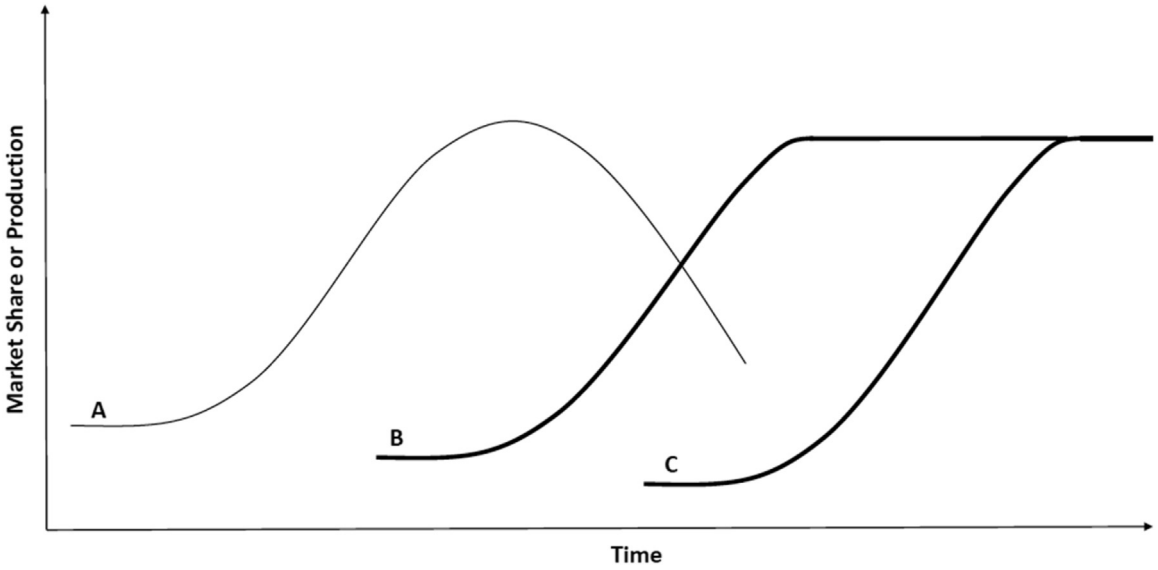

Fig. 6. Coexistence of leadership.

economists identify high exchange rates (weaker values of local currencies) as drivers of initial catching (e.g., Katz, 1995). However, these factors alone cannot enable these countries to achieve world leadership.

Initial factor cost differences and relocations of related factory represent favorable initial conditions through which latecomers assimilate existing technologies through learning by doing. Such a process enables them to generate revenues for further investment in production technologies. Given this phenomenon, initial catch-up in market shares by latecomers is often realized in the low-end segment of the market, similar to the case of steel and software industries (Lee and Ki, 2017; Mani, 2013). Catch-up based on the advantages of factor cost is not rare, but does not automatically lead to the eventual reversal of market shares between the incumbent and the latecomers.

The sectoral system factors, initial conditions and macro factors could support the entry of a latecomer. Public policy is one factor that may play a role in the entry stage. Other actors in the sectoral system, such as financial organizations, may also play a similar role. These factors facilitate the entry and growth of new firms in an industry. Local firms in latecomer economies may enter and emerge in different ways with or without support from the government. These firms may also assume control of the equity shares held by multinational companies in a joint venture partnership (e.g., Samsung's take-over of the shares held by Sanyo in the electronics industry as discussed in Lee and He, 2009) or the result of the establishment of state-owned enterprises (e.g., POSCO in Korea and other enterprises in China).

3.3.2. *Gradual catch-up*

Low wage rates and the low value of local currencies are sources of initial catch-up. However, these factors do not often trigger a process that could eventually lead latecomer firms to reach or even overtake the leaders. These factors cannot explain how initial cost advantages in production or low currency value may lead latecomers to gain advantages in other dimensions, such as product differentiation, high-end products, sectoral upgrade, and innovation. An example is the case of Korea, which used to provide low wage-based production sites to Japanese firms but emerged as a formidable rival to Japanese firms in high-end goods markets.

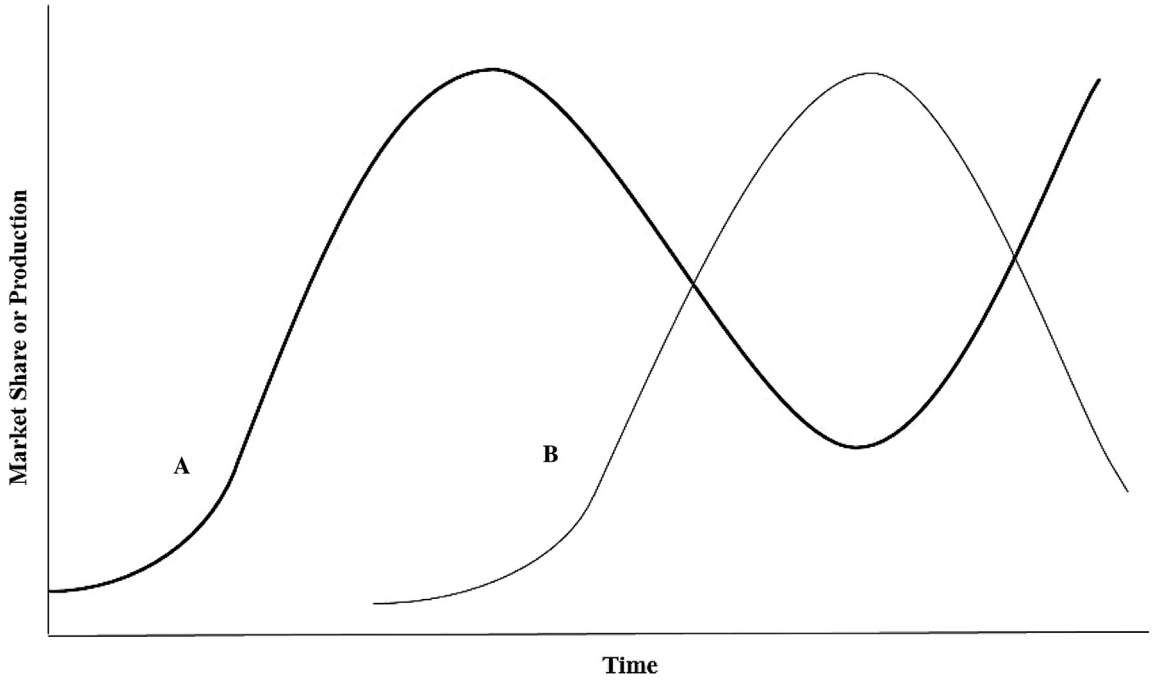

Fig. 7. Return of Old Leadership.

The key factors for gradual catch-up are learning and building of capability as documented in the works of Bell and Pavitt (1993), Kim (1997), and Lall (2001). The long term accumulation of advanced capabilities by domestic firms represents a necessary condition for catching up to a level of world leadership. Other system factors besides public policy and financial organizations that are already relevant in the first stage also become significant. These factors include high-quality human capital from advanced educational organizations, public research organizations, networks of related firms, and vertical links with suppliers and users. Some of these system factors are sectoral, but several of them are national and therefore affect all sectors; this finding was highlighted in the literature on national innovation systems by Freeman (1987), Nelson (1993), and Lundvall (1992). According to Malerba and Mani (2009) and Malerba and Nelson (2011), different types of actors, networks, and institutions have affected the gradual catching up of countries in various sectors. For example, the role of the government in the entry of latecomer steel firms was critical in Japan and Korea. The Japanese and Korean governments supplied large chunks of investment funds that were used to bankroll these firms. In other sectors government regulations against foreign incumbent firms resulted in asymmetric conditions for market competition, which enabled latecomers to increase their market shares. This strategy was used by the Chinese government in developing its ICT industry.

Companies may differ in their strategies and growth. Domestic firms grow because they operate through original equipment manufacturing (OEM) or through sub-contracting for foreign MNCs, similar to the early days of Hyundai Motors or Samsung's memory chip factory. Given their cost advantage, these firms focus on fixed capital and achieve productivity increases in low-end segments of the product range, which enable them to augment their market shares. These domestic firms gradually accumulate production capabilities via learning-by-doing. These firms then move up the quality ladder of products and technologies. The stage of gradual catch-up often corresponds to a path-following strategy, in which the latecomer moves along the same technical trajectories as the incumbent but at a low cost (Lee and Lim, 2001).

3.4. *Late stages of catch-up cycles: forging ahead and change in leadership*

The previous factors discussed in Sections 3.2 and 3.3 may explain the entry and the gradual catch-up of latecomer countries as demonstarted in a large part of literature on development and catch-up (we do not quote the wide variety of contributions in this regard). To enable a latercomer to forge ahead, change must occur in global leadership from the incumbent to the latecomer accompanied by a decline of the incumbent. To explain these dynamics, we propose the application of two additonal concepts related to the dynamics of sectoral systems, namely, windows of opportunities and responses of the latecomer and the incumbent. In successive catch-up cycles and changes in industrial leadership, the forging ahead stage of the latecomer country (Stage III) corresponds to the decline stage (Stage IV) of the incumbent country. For clarity and simplicity, we will discuss these two stages together.

3.4.1. *Windows of opportunity*

Perez and Soete (1988) introduced the concept of "windows of opportunity". We extend the notion of windows of opportunity to various building blocks of a sectoral system. We propose that an industry experiences changes in one or more of the basic components of the sectoral system. These experiences open up a window of opportunity for the forging ahead of the latecomer. These windows of opportunity are related to technology and knowledge (a technology window), demand conditions, and business cycles (a demand window), as well as public policy and institutional setting (an institutional window). To maintain the analysis at a tractable level, we consider these windows as exogenous to firms.

The *first window of opportunity* is the appearance of a new technology or radical innovation. When a new technology or radical innovation is introduced, the incumbent may fall behind if it is locked-in to the existing technology, where it holds a dominant position. This situation is known as the "incumbent trap" (Chandy and Tellis, 2000). The incumbent tends to stick to existing technology because its capabilities and investments are related to such

technology. For example, the shift from analog to digital technologies provided the critical opportunity for Korean electronics firms to seize control of the market from Japanese firms; for instance, in the display industry which was analyzed in Lee et al. (2005). A company may adopt a cautious attitude with respect to the new emerging technology because such a company considers emerging technologies inferior or subject to a high degree of uncertainty; this case is exemplified by the S-Curve path of technologies in Chandy and Tellis (1998) and Foster (1986). The incumbent then continues to use the current technology and tends to ignore the possible destructive potential of new technology or new products, in other words similar to the notion of disruptive innovations (Christensen, 1997). The new competences required for new technology may also differ significantly from the ones utilised by the established leader, as in the case of competence-destroying technology (Tushman and Anderson, 1986; Henderson and Clark, 1990).

The *second window of opportunity* originates from another component of the sectoral system, namely, the demand of users and consumers. This window refers to the opportunity provided by the creation of a new demand. Leaders do not respond to this new demand because they are successful within their existing markets and customers. If the new demand grows rapidly, the effect may provide ample possibilities for late entrants to catch up. The demand window may refer to the rapid growth of domestic demand, which is not satisfied by exports from leading countries or by the local production of multinational corporations. This case is illustrated by the explosive growth of demand in China in several sectors that resulted in the subsequent entry and growth of many Chinese firms. The third type of demand window refers to business cycles and/or abrupt changes in market demand. Although business cycles have long been the subject of research in economics, their link with strategic choices made by firms, particularly latecomers, has not been explored sufficiently. Mathews (2005) and Lee and Mathews (2012) pointed out the role of business cycles in serving as a window of opportunity for latecomers in industries characterized by large investments (e.g., semiconductors). According to Mathews (2005), upturns create opportunities for incumbents to harvest profits and expand production and markets, while downturns play a cleansing role. This situation forces weak players into bankruptcy, thereby releasing resources to be utilised by either stronger incumbents or challengers aiming to enter the industry. Mathews (2005) argued that upturns belong to incumbents, whereas downturns belong to challengers, providing a window of opportunity. In general, during business cycles, a mismatch occurs between the dynamics of investment and production on the one hand, and the dynamics of market demand on the other hand. These circumstances require incumbents and latecomers to make strategic choices in timing and capacity because they can be pushed out of the market if they fail to do so.

A *third window of opportunity* may be opened up by public policies or by other institutional changes. Governments may intervene through the establishment of R&D programs that affect the learning process and the accumulation of capabilities of domestic firms or through the provision of subsidies, tax reduction, export support, regulations, and public standards. The catch-up perspective suggests that the government creates an asymmetric environment in which incumbent firms (often foreign) are in a disadvantageous position (in terms of taxation, entry restrictions or marketing restrictions) at least in the domestic market of a country. Asymmetries could result in advantages for latecomers who can offset initial cost disadvantages associated with the entry. These interventions are often inconsistent with fair competition, but they are sometimes justified because incumbents often use unfair measures to deter the entry of latecomers (see the discussion in Kim and Lee, 2008). The importance of active government policies in the catching up of countries (e.g., Korea and China) in several sectors is discussed by Malerba and Nelson (2012). Other examples are provided by public policy in the Chinese telecommunications equipment industry (Mu and Lee, 2005), as well as in Taiwanese industries (Mathews, 2002). At the institutional level, Guennif and Ramani (2012) showed how changes in the regulatory system opened up opportunities for Indian firms in the pharmaceutical industry.

Windows of opportunities could open up simultaneously or sequentially in the same industry. Lee et al. (2014) observed that the emergence of new technology followed by regulatory changes on foreign firms served as windows of opportunity that enabled domestic Indian firms to achieve success in the IT service sector. Giachetti and Marchi (2017) noted that windows of opportunities related to digital GSM technology are associated with a demand window related to individual users and with an institutional window related to EU support for digital GSM standards in the change of leadership from the American-based Motorola to the European-based Nokia.

In our framework, windows can be exogenous or endogenous, depending upon responses by the various actors of a sectoral system. For example, a technology window may result from R&D investments of firms in new technologies. Alternatively, a new window could be related to a new demand that addresses opportunities opened up by the R&D and marketing efforts of latecomer firms. Another example is an institutional window created by new public policy as a result of the lobbying by latecomer companies in a country that aims to catch up. Therefore, the exogeneity or endogeneity of major innovations depends on who is initiating changes in technologies within or outside the sectoral system. As far as new technologies are concerned, current leaders may have good reasons to lead innovations that enhance competence, especially when they address several alternative directions for technical change. If leaders succeed in developing new technology and in establishing an industry standard, they are likely to maintain their leadership position into the next generation. This case is exemplified by Samsung's domination of memory chip production since the late 1990s (Shin, 2017). This and other examples relate to certain technologies (e.g., semiconductor memory chips or capital goods) that have a degree of cumulativeness, high barriers to entry, and are not end-products to final consumer goods (e.g., mobile phones).

Even in cases of exogenous technological windows for latecomers, successful latecomers may "endogenize" exogenous innovations. An example of this is Samsung's co-development (in its early stage) of CDMA wireless technologies with Qualcomm (Lee and Lim, 2001) and the development of the world's first digital TV set through a public–private R&D consortium in Korea (Lee et al., 2005). The initial development of technologies in both cases occurred in advanced countries. The latecomer quickly identified the first mover (Qualcomm in the case of CDMA technologies) and worked together for the commercialization of developments of the source technology. In the development of digital TV, the Korean consortium monitored the progress of the standardization process among key players in advanced countries, which then enabled the firm to develop a digital TV compatible with the final standard agreed upon by key players (Lee et al., 2005). This strategy of "endogenizing" exogenous new technology at an early stage may be one of the key ingredients of successful leapfrogging by latecomers, which depends on the concurrent possession of advanced capabilities by latecomers.

3.4.2. Response to the opening of a window: latecomers vs. incumbents

Forging ahead often depends on the opening of a window and on the effective response of firms and other system components of a latecomer country. Latecomer firms recognize a window that has opened up and take advantage of such opportunity, but these firms

are supported by other system factors in their drive to grasp such an opportunity.

The successful responses of latecomer firms are usually associated with high levels of learning and of absorptive technological and marketing capabilities. These capabilities enable them to identify and grasp new opportunities and implement innovations for their benefit. The presence of learning and technical capabilities at the system level is complemented by other actors, networks, and institutions that support the catch-up process. The set of actors, networks, and institutions depend on a specific sector, but we can mention some of them here. They include effective institutional setting in terms of public policy and regulation, a strong university and public research system, supply of advanced human capital, presence of networks of suppliers and collaborating firms, and availability of finance for innovation.

Given these structural conditions, some processes and behaviours are set in motion to ensure the successful response of a latecomer to the opening of a window. First, domestic firms must identify and commit to the opportunity that has opened up. Firms must also continue to strengthen efforts to learn and innovate. They may focus on specific areas of technology or segments of demand to facilitate effective performance. The timing of the investment and access to new knowledge and technology are key factors for consideration in technology window. At the level of other system components, public policy often supports the efforts of domestic firms. Similarly, the R&D funding of the government must also change in terms of the scale and quality of support provided. Financing of new initiatives must be readily accessible to ensure that university research is strengthened and upgrades in education program are initiated. Finally, the realignment of other institutions, such as regulation and standardization, goes hand in hand with the new sectoral setting.

Forging ahead is often triggered by a stage-skipping or path-creating strategy of firms (Lee and Lim, 2001). A stage-skipping strategy refers to the case of latecomer firms that follow a similar path to the incumbent but skip some stages, thereby saving time during the catch-up process. By contrast, a path-creating strategy refers to the exploration of one's own technological development by taking advantage of a new radical innovation or a new generation of technologies. This approach enables a latecomer to create its own path, one which diverges from the path taken by its forerunners (Perez and Soete, 1988).

The response of the incumbents and the system components related to the opening of a window may not be quick or effective. Incumbents tend to be complacent with their current success, causing them to neglect new technologies, disruptive innovations, new types of demand, and/or growing markets. Incumbents then fall into a lock-in trap of sticking to old technology while delaying the adoption of new ones. By contrast, latecomers may enjoy the advantage of the freedom to choose the most up-to-date or emerging technologies available. Traps for an incumbent that faces the choice of adopting (or not adopting) new technologies may only arise *ex post*. New technologies are often costlier, less productive, and less reliable than existing ones. The incumbent who commands the highest productivity from existing technologies finds no reason to adopt new technologies. This situation explains the difficulty of determining whether the incumbent's choice is simply a mistake or an *ex ante* rational decision. The boundary of an incumbent trap is broad enough to include diverse cases, including "disruptive innovation" (Adner, 2002; Adner and Zemsky, 2006) and the "innovator's dilemma" of whether or not to introduce innovations that may be detrimental to its current business (Christensen, 1997). This broad definition of the incumbent trap can be illustrated by the case of Motorola, which attempted to improve existing analog telecommunication technologies despite the arrival of digital technologies. According to Giachetti (2013) and Häikiö (2001), even when the digital standards are quickly diffused in numerous countries because of their superior technical performance, Motorola insisted on investing heavily in analog mobile phone technologies, given their belief that customers would accept the technological trajectories imposed by its leadership.

As with firms, the other components of the incumbent's sectoral system may not be effective in reacting to the opening of a window. The cases presented by Mowery and Nelson (1999) and Malerba (2004) indicate numerous examples of delayed responses by research or training organizations, financial systems, the government and other institutional settings in advanced countries. For example, education may be locked-in to old technologies, finance may be too short-sighted and directed towards funding existing technologies, regulations may be too stringent with respect to novelty, and public policy may be myopic and tend to support low-risk R&D projects only.

In summary, different trajectories can be created across industries depending on windows and responses. Thus, different catch-up cycles can be generated. Some latecomer countries (i.e., the successful ones) may enter the stage of changes in industrial leadership, whereas others (i.e., old latecomers that have become leaders but later on fail to respond appropriately) enter the stage of decline.

4. Formal model of conceptual framework

A formal model of the conceptual framework is presented in this Special Issue in the article by Landini et al. (2017), which develops a history-friendly model of the role of technological conditions in the emergence of catch-up cycles. The model is inspired by two cases where the arrival of a radically new technology ushered in leadership change – mobile phones and semiconductors. The model focuses on the commonalities of the catch-up cycles in these two industries, namely, the arrival of new technologies providing a window of opportunity for latecomers, the response of incumbents and latecomers to such an opportunity, the advantages of latecomers in technological upgrade, and the role of a country's characteristics in favoring the catch-up of latecomers.

In its baseline form, the model features the benchmark case of three catch-up cycles that have experienced leadership changes twice. The simulation analysis shows that a leadership change is likely to occur as a result of the following conditions: a) the disruptiveness of the new technology; b) ineffective response by incumbents (e.g., pronounced lock-in behavior); and c) effective response by latecomers (e.g., rapid adoption of new technologies or a better learning ability of the firms in a particular country).

The model replicates the catch-up cycles of the two industries on which it is based, and can also generate other types of cycles present in other industries. This is made possible by assigning different values to parameters related to various factors, such as the magnitude of the technological window, the degree of the incumbents' lock-ins and their initial capabilities, the characteristics of the national system of innovation of the latecomer, and the status of the current technological landscape. Five distinct types of catch-up cycles have been generated. The first type is a standard cycle where a clear change in the market leadership occurs. An aborted catch-up cycle also exists with a limited rise of the market share of late entrants. In the model of Landini et al. (2017), the aborted catch-up case is associated with a window of limited size, which does not allow late entrants to gain the necessary momentum and keep pace with the leaders.

The third type of catch-up cycle is persistence of leadership where the incumbent maintains its leadership. This persistence of leadership is exemplified by the case of Japanese firms (e.g., Canon in the camera industry) or of Korean firms (e.g., Samsung in the

Table 1
Events of Leadership Change and Persistence in Six Sectors.

Events/ Time	Mobile Phone	Memory	Camera	Jet	Steel	Wine
Event (I)						
Time	1998	1982	Mid-1960s	1995	1980	Mid-1990s
Main actors	USA (Motorola) → Finland (Nokia)	USA → Japan	Germany → Japan	Netherlands (Fokker) → Canada (Bombardier)	USA → Japan	Old World (France, Italy, etc.) → New World (USA, Australia, etc.)
Event (II)						
Time	2012	1993	1980s–2010s	2005	1998	Mid-2000s
Main actors	Finland (Nokia) → South Korea (Samsung)	Japan → South Korea (Samsung)	No change (Japan was the persistent leader despite the development of digital SLR camera.)	Canada (Bombardier) → Brazil (Embraer)	Japan (Nippon Steel) → South Korea (POSCO)	Return of Old World
Event (III)						
Time		1993–2016	Mid-2010s			
Main actors		No Change (South Korea was the persistent leader.)	Change likely with substantial rise of new entrants			
No. of EVENTS	2	3	3	2	2	2

memory chips industry). In the model of Landini et al. (2017), the persistence of leadership is enabled by lesser lock-ins of incumbents with respect to new technological windows, which allow them to respond promptly to technological discontinuities. The fourth type of catch-up cycle involves the return of the old leadership with the old incumbent's return to leadership after losing its position to a latecomer. This situation corresponds to the case of the wine industry where Italy substantially regained market shares in the 2000s, as well as the video game industry in which industrial leadership shifted first from the US to Japan and then back to the US (Izushi and Aoyama, 2013). In the model of Landini et al. (2017), the incumbent's comeback is attributed to an increase in the average level of capabilities that incumbent firms are endowed with at their inception and from the strength of the national system of innovation of the incumbent. The fifth type of catch-up cycle is characterized by the coexistence of leadership between incumbents and latecomers. This phenomenon is exemplified by the wine industry in the 1990s, a traditional industry in which the old leader (i.e., France) is joined by new leaders from among late entrant countries (i.e., US, Australia, and others). In the model of Landini et al. (2017), coexistence is achieved by introducing discontinuities of a smaller size and decreasing returns to technological investments, something which is typical of traditional industries.

5. Empirical evidence of catch-up cycles in six industries

The framework discussed in the previous section was applied to the long-term evolution of six industries: mid-sized aircraft (Vértesy, 2017), mobile phones (Giachetti and Marchi, 2017), wine (Morrison and Rabellotti, 2017), semiconductor memories (Shin, 2017), camera (Kang and Song, 2017), and steel (Lee and Ki, 2017). These industries are examined in detail in this Special Issue. The next pages summarize the main results obtained through the empirical analysis of these industries. We briefly mention changes in or persistence of leadership, and the role of the windows of opportunity and the responses by actors in each sector. Table 1 summarises the events of changes in or persistence of leadership (Event I, II and III) in six industries. The cases of leadership changes include 11 events. Persistence of leadership is involved in two cases, namely, memory chips since 1993 and cameras in the 1980s. One case refers to the return of the incumbents (in the wine sector since the mid-2000s).

Leadership in the **mobile phone** industry changed twice with an interval of 14 years (Giachetti and Marchi, 2017). The first change was in 1998 when Nokia dethroned Motorola. The second leadership change occurred with the transition from the first generation mobile phones to smartphones when Samsung dethroned Nokia in 2012 in terms of market shares. Technological change played a significant role in opening up windows of opportunity for newcomers in both leadership change events. In the transition from Motorola to Nokia, the opportunity was created by the emergence of digital technology. In the transition from Nokia to Samsung, a technological opportunity was opened up by a major technological change, namely, the shift from digital phones based on older mobile operating systems, such as Nokia's Symbian to smartphones using Google's Android OS, which was custom-built to support the touch interface. Such an opportunity was rapidly grasped by Samsung, the first mobile phone vendor to incorporate the Android OS.

A window opening stemming from a change in demand also played an important role in the first event. This change involved the rapid increase in individual phone users, not just business users. In the second event, demand rose rapidly as the touch interface gained popularity with consumers. The two events differed with respect to the significance of opportunity windows associated with institutional change. In the first event, a significant opportunity was opened up by the EU's exclusive support for digital GSM standards compared with the support for multiple standards in the US. In the second event, Nokia's decline was caused by the incumbent's trap-like behavior of sticking to the old operation system and its hesitation in launching smartphones in the early 2000s.

The **memory chip** segment in the semi-conductor sector experienced two leadership changes, with an interval of 11 years. The first change was from the US to Japan in 1982, and then from Japan to South Korea in 1993. Korean companies have retained industrial leadership for more than 20 years and no sign of any change in the near future is observable (Shin, 2017).Thus, this sector involves two cases of leadership change and one of persistent leadership.

Overall, the technological regime in the memory chip sector was characterized by rapid technological progress with generational changes of products being developed every three to four years. Thus, late entrants had to pursue moving targets; they forged ahead by simultaneously developing two (current and next) generations of technologies and by taking advantage of the cyclical and predictable nature of technological change (Shin, 2017). At the level of specific generational changes, opportunities opened up for Japanese firms to enter and catch up as the trajectory of very large-scale integration (VLSI) moved through the 1K and 4K DRAM generations, and then to forge ahead as further windows

opened up with the major step jumps to 16K and 64K. Opportunities opened up for Samsung when the industry moved to the 4M and 16M generations (Shin, 2017). These discontinuities created significant opportunities for the latecomers not merely to enter the industry (the Perez and Soete argument) but also to catch up and forge ahead of incumbents. Then, the persistence of the leadership by the Korean firms since 1993 can be explained in terms of both capability expansion of the incumbents, as well as two new technological developments that favored incumbent leaders – the weakening of commodity-like characteristics of memories due to a sharp increase in the number of technological standards, and the increasing "economies of scope" that mainly emerged in the production of DRAMs and flash memories. These changes have narrowed the "technology window" for latecomers.

Demand-related windows in the memory chip sector played a role, too. For instance, in the two leadership change events, the incumbents tended to be highly cautious or conservative in investing during the downturns, whereas the late entrants pushed on with larger investment during the downturns to prepare for the next generation of technologies (Shin, 2017). Institutional factors were noted to a certain extent. In the case of the leadership shift to Japan, the VLSI project, which was coordinated by the government, stimulated the development of the knowledge base and associated investment by Japanese firms. This development facilitated their response to the windows of technological opportunity. However, in South Korea, the government was suspicious of the prospects for developing a semiconductor industry and did not play a facilitating role in supporting the entry by Samsung. In the case of the rise of the Korean firms, there was a different kind of institutional change that happened in the incumbent countries, namely, the 1986 Semiconductor Trade Agreement (STA) between the US and Japan. The agreement was intended to limit the fierce price competition between Japanese and US producers by setting a price floor for DRAMs in the US market. However, the agreement delivered windfall gains to Japanese producers, but it also opened up an opportunity for Korean producers to consolidate their growing position in the international market (Shin, 2017).

The **camera** industry experienced three major technological shifts (Kang and Song, 2017). Changes in industrial leadership were associated with the first and third shifts, but the incumbents retained their leading market during the second shift. The first leadership change occurred in the mid-1950s when German companies manufacturing rangefinder (RF) cameras were replaced by Japanese firms on a new technological path involving the development of a single lens reflex (SLR) camera. The second technological shift in the 1980s from analog SLR to digital SLR (DSLR) was not associated with any change in leadership away from the established Japanese firms, such as Canon and Nikon. In 2010, the invention of the mirrorless camera led to new or late entrants, such as Sony, Olympus, and Samsung. These entrants claimed larger market shares in some segments or in Asian countries than the old incumbents. Thus, the leadership shift from Germany to Japan in the mid-1960s (Event I) was significantly influenced by the opening of a technological window of opportunity associated with the emergence of the SLR camera technology. This radical technological shift challenged both the market dominance of the RF camera and the competence base of its producers. This technology was originally developed by German companies, but Japanese companies were the ones that adopted, improved, and commercialized the technology. As a result, German firms fell into the incumbent trap of not adopting this innovation. In the 1980s, further substantial technological change occurred as digital technology was incorporated in cameras. This change involves a shift from film-based photography, similar to SLR, to electronic imaging in digital SLR. However, a large part of the DSLR technology was developed primarily from existing SLR technology. The digital image sensor/storage/display system was the only component that was significantly novel. By that stage, Japanese producers and their suppliers had developed substantial expertise in these areas of digital technology. Thus, instead of being a competence-destroying technological discontinuity, the shift to DSLR technology was a "competence-reinforcing" discontinuity that contributed to the persistence of Japanese leadership for more than two decades (Event II). Recently, further technological discontinuity emerged in the mid-2000s that involved a bundle of novel technologies underlying the development of the mirrorless camera. For Japanese incumbent leaders, this technological discontinuity was a substantially "competence-destroying" technological trajectory, but it provided a significant opportunity for hitherto minor Japanese players in the industry (primarily, Panasonic and Sony) and Samsung in South Korea. These firms committed to developing the emerging mirrorless technologies as a basis for challenging the incumbents' dominant position. In early 2010, these companies achieved substantial growth in market share to establish strong positions among global market leaders (Event III).

Demand surges provided significant opportunity windows in both cases of industrial leadership change, especially in connection with the first change (Event I). Demand for cameras rose rapidly in Japan during World War II and persisted during the post-war US occupation and the Korean War. This demand surge provided a basis for Japanese producers to ramp up mass production and develop an associated structure of component suppliers. In the second case of leadership change (Event III), user dissatisfaction with the limitations of the SLR and DSLR cameras grew strongly in the quality-sensitive Japanese and South Korean markets (both professional and personal). This event created a latent demand that could not be met by incremental improvements to such technological vintages. The incumbents made a delayed response, but this opportunity for change was quickly exploited by Japanese latecomers and Samsung.

The **steel** industry experienced two leadership changes or catch-up cycles (Lee and Ki, 2017). The first was from the US to Japan in the late 1970s and early 1980s, and the second from Nippon Steel to POSCO in South Korea during the late 1990s. Leadership shift from the US to Japan involved technological and institutional windows. The Japanese firms immediately adopted the Austrian-made innovation of the basic oxygen furnace (BOF) method and further improved such method by follow-on innovations. The Japanese government was also involved by arranging a collective licensing of the BOF method for significantly reduced royalty fees (Nakamura and Ohashi, 2008). By contrast, US firms fell into the incumbent trap of sticking with existing methods. Path creation by Japanese firms was along the mode of adoption and follow-on innovations. The experience of the Japanese industry closely matches the two integral components of Perez and Soete's proposition because a window of opportunity opened up that allowed the industry to engage in the BOF method during the early stage of its technology cycle when the Japanese firms accumulated substantial operational and innovative capabilities in relevant areas of steel-making. Thus, the Japanese took advantage of that opportunity and engaged in the BOF method at an early stage and at a low cost (the licensing cost) because of government–industry coordination.

The case of South Korea presents a different story. In the 1970s, the opportunity also opened for the Korean industry to enter at an early stage in the development of continuous casting (CC) technology. However, POSCO was only starting at the time with limited steel-making capabilities. Thus, POSCO did not take the opportunity to use CC technology. Instead, POSCO moved successfully into the path-following mode of learning and gradual catch-up stages based on the mature technology imported from Japan. POSCO's process of forging ahead would not have been possible without their decision to build the second mill. Had this second mill failed to achieve comparable competitiveness to that of the incumbent in

terms of productivity, catching up with Nippon Steel would not have been possible. Comparable competiveness became possible because POSCO was able to purchase and install state-of-the-art technologies at low costs because of the second oil shock. Thus, the downturn in the steel industry provided a window of opportunity for POSCO because incumbent firms were less reluctant to sell such technologies or to charge low prices,

The **regional jets** industry has experienced two leadership changes in the past three decades (Vértesy, 2017). The first instance was in 1995 when British Aerospace (BAe) and Fokker lost their leadership position to Canada's Bombardier, which created a niche for the 50-seat market. BAe and Fokker were the European incumbents in the sector with a product line that covered the 70 to 120 seat range. The second leadership change occurred in 2005 with the rise of the Brazilian Embraer. Changes in demand in this industry served as the window of opportunity in both instances of leadership change. Several trends converged in the first shift from European firms to the Bombardier in the late 1990s. These trends creates a rapidly growing demand for small jet aircraft, which signalled a shift from the 70- to 120-seat range to the 50-seat segment. Demand shifts in the second change of leadership from Bombardier to Embraer in the mid-2000s reverted to the 70- to 120-seat market segment, which raised the 50-seat regional aircraft to a 150- to 180-seat range. These shifts resulted in rising competitive pressures on airlines to be cost-efficient by matching aircraft size with route patterns and by investing in fuel-efficient aircraft in an era of rising fuel prices.

The emergence of demand-related opportunity windows was reinforced in the events in leadership change and regulatory changes in the US. Following the growth of regional routes in the 1980s, agreements between the US pilots' unions and the airlines included "scope clauses"; such clauses defended the relatively high wages of pilots with large legacy airlines by restricting subcontracted pilots on regional and feeder routes from flying aircraft with more than 50 seats. This agreement effectively excluded large aircraft from the regional/feeder market, thereby reinforcing the shift in demand toward new aircraft below that threshold. In the 2000s, the scope clauses were relaxed from 50 seats to 70 seats and beyond, which reflected the converging of market pressure on the 75- to 120-seat segment. This change reinforced the significance of demand opportunity focused on that segment. In the leadership shift to Embraer (Event II), a spectrum of institutional changes in the latecomer's domestic context (the privatization of Embraer, and financial and export support schemes offered by the government) facilitated Embraer's exploitation of the opportunity window that was opened up by demand changes.

The case of the **wine** industry (Morrison and Rabellotti, 2017) involves "new world" producers (primarily, the USA, Australia, South Africa, and other later entrants, such as Chile) in competition with "old world" producers (mainly, France and Italy). Until the end of the 1980s, the international wine market was dominated by European countries. France was the leading country in the wine industry followed by Italy. Two new global leaders emerged in the early 1990s, namely, the US and Australia. The mid-1990s can be identified as the period when new world producers substantially expanded because their global export market share increased compared with that of Old World producers. This period involved the co-existence of the old and new leaders after the substantial rise of the new entrants. The second period is from the early 2000s to the present, which is characterized by the return of old world producers, particularly Italy. The demand window involving the substantial increase of new world producers in the 1990s was related to the emergence of new, inexperienced consumers from the UK, the US, and Scandinavian countries. The demand window involving the return of old world producers in the first decade of the 2000s was related to sophisticated and varied wines in new and more traditional markets and an upsurge of the Asian market. This industry is another case in which radical technological discontinuity did not play any role in opening up windows of opportunity for latecomers. Such an implication does not disregard the fact that considerable technological catching up and incremental innovation by latecomers, and changes in the organizational basis of their innovation systems, were important in Event I when new world producers achieved a substantial increase in their share of the global market. However, those activities were part of the latecomers' response to a significant window of opportunity that opened up by demand- and market-related factors. These factors include a combination of changing consumer tastes in existing markets, the emergence of new wine-drinking markets, and a major change in the international channels for distribution and marketing.

Policy and regulation played a major role in reinforcing the emergence of the demand-driven window of opportunity for new world producers in Event I. This event was related to the regulatory environment of old world producers, namely, the combination of EU subsidy and regulatory controls that locked incumbents into existing products, markets, and technologies. The radical reform of this institutional environment in the late 2000s played a significant window-opening role in the comeback of old world producers (Event II) when they became the latecomers who sought to recapture a significant market share in the new type of wine industry that was created through the efforts of new world producers (Morrison and Rabellotti, 2017).

7. Concluding remarks

The current study on catch-up cycles was initially motivated by the "window of opportunity and leapfrogging" thesis of Perez and Soete (1988). The current article and the companion papers in this Special Issue have extended and modified their thesis and offered a conceptual framework of a catch-up cycle within a sectoral system view. This framework consists of (a) four stages (i.e., entry, gradual catch-up, forging ahead, and falling behind), (b) three main windows of opportunity (i.e., technology, demand, and institutions/public policy) related to changes in a sectoral system, and (c) the responses to the opening of windows of opportunity by firms and other components of the sectoral system. Perez and Soete (1988) focused on leapfrogging that takes advantage of a new technological paradigm. By contrast, we propose that leapfrogging tends to relate to the forging-ahead stage. However, this relation only applies to qualified latecomers that have an accumulated level of capabilities and an effective system that supports their effort.

Our answer to the initial question on the sources of successive changes in industrial leadership is the fact that diverse windows of opportunities tend to emerge often and unexpectedly. While we consider all three types of window, the final picture derived from empirical evidence offered by the six sectors is essentially "Schumpeterian" because it confirms that exploiting a technological window is very critical to forging ahead. Demand-related windows are important, but they tend to influence the forging-ahead stage because they lead to demand-driven innovation and new investment or demand-driven adoption and diffusion of new technologies. Similarly, although the role of the institution/public policy window is significant in several cases, its actual impact is realized through the adoption or diffusion of new innovations. This article also proposes that we qualify and specify the subtle nature of technological windows along the dimension of competence-enhancing versus competence-destroying innovation. And we also claim that analysis of the various windows must be complemented by an examination of the nature and types of capabilities and strategies (of both the incumbent and latecomer firms) and of the

responses to the window by the other components of the sectoral system.

The empirical analyses of the six sectors also confirm the great sectoral heterogeneity in terms of the presence and role of different windows in different sectors and of system responses. We also find that the incumbent in sectors with significant demand windows does not fall victim to a drastic replacement but tends to coexist with new entrants. By contrast, some cases with significant technology windows experience a radical collapse of incumbents (similar to that in the mobile phone sector). This condition is also confirmed by the simulation results of a history-friendly model of successive catch-ups in industry evolution (Landini et al., 2017); these results show that changes in technology windows (particularly those that are large in terms of technological advancements) may lead to a quick and radical reversal of market shares.

One final remark concerns policies. Latecomers must be ready to respond to the opening of a window for catch up and they should not waste this opportunity. New windows of opportunity tend to open up unexpectedly. Thus, latecomer countries should be prepared to build sector-specific capabilities that support actors, networks, and institutions. These capabilities may subsequently lead to innovation and growth. However, capability-building preparation may take time. In contrast, incumbents must be cautioned against lock-in or trap-like behavior and the possibility of sectoral system misalignments. They may be motivated to develop major innovations in order to sustain their leadership.

The successive catch-up cycle framework may also provide policy implications that are more effective than those related to the product life cycle theory, which is limited to the entry and gradual catch-up stages of development. Cost differences provide favorable initial conditions for latecomers that enable them to familiarize themselves with existing technologies (i.e., learning by doing) and eventually generate revenue for further investments in production technologies. This type of catch up based on factor cost advantages is not rare, but it does not easily lead to the eventual reversal of market shares between the incumbent and the latecomer unless the latter develops high level capabilities combined with local ownership of production and R&D and a sectoral system that is effective in sustaining innovation and growth. The catch-up cycle is likely to be aborted if latecomers fail to keep upgrading their capabilities and taking advantage of the windows of opportunity. Then, they might become stuck in the middle-income trap in which a latecomer economy fails to upgrade to high value-added products and is confined to performing activities with low value in the global value chain (World Bank, 2012; Lee, 2013). The framework of catch-up cycle suggests a useful policy for middle-income developing countries. These countries are encouraged to move beyond that stage and escape the middle-income trap. This framework proposes a policy agenda centered on building capabilities for creating innovations to seize a window of opportunity and on the development of a system that is effective in responding to the opening of catch-up opportunities.

References

Adner, R., 2002. When technologies are disruptive: a demand based view of the emergence of competition. Strateg. Manage. J. 24 (10), 1011–1027.

Adner, R., Zemsky, P., 2006. A demand perspective on sustainable competitive advantage. Strateg. Manage. J. 27 (3), 215–235.

Bell, M., Pavitt, K., 1993. Technological accumulation and industrial growth: contrasts between developed and developing countries. Ind. Corp. Change 2, 157–210.

Chandy, R.K., Tellis, G.J., 1998. Organizing for radical product innovation: the overlooked role of willingness to cannibalize. J. Mark. Res. 35, 474–487.

Chandy, R.K., Tellis, G.J., 2000. The incumbent's curse? incumbency, size, and radical product innovation. J. Mark. 64, 1–17.

Christensen, C.M., 1997. The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Harvard Business Review Press.

Fagerberg, J., Srholec, M., Knell, M., 2007. The competitiveness of nations: why some countries prosper while others fall behind. World Dev. 35 (10), 1595–1620.

Fagerberg, J., Srholec, M., Verspagen, B., 2010. The role of innovation in development. Rev. Econ. Inst. 1 (2).

Fagerberg, J., 1988. International competitiveness. Econ. J., 355–374.

Foster, R.N., 1986. Innovation: The Attacker's Advantage. Macmillan, London.

Freeman, C., 1987. Technology, policy, and economic performance: lessons from Japan. Pinter Publishers, London & New York.

Giachetti, C., 2013. Competitive Dynamics in the Mobile Phone Industry. Palgrave Macmillan, UK.

Giachetti, C., Marchi, G., 2010. Evolution of firms' product strategy over the life cycle of technology-based industries: a case study of the global mobile phone industry, 1980–2009. Bus. Hist. 52, 1523–1550.

Giachetti, C., Marchi, G., 2017. Successive changes in leadership in the worldwide mobile phone industry. Res. Policy 46, 352–364.

Gu, S., Lundvall, B.A., Liu, J., Malerba, F., Schwaag Serger, S., 2009. China's system and vision of innovation: an analysis in relation to the strategic adjustment and the medium- to long-term S&T development plan (2006–20). Ind. Innovation 16 (4–5), 369–388.

Guennif, S., Ramani, S.V., 2012. Explaining divergence in catching-up in pharma between India and Brazil using the NSI framework. Res. Policy 41, 430–441.

Häikiö, M., 2001. Nokia—The Inside Story. Edita, Helsinki.

Henderson, R.M., Clark, K.B., 1990. Adm. Sci. Q. 35, 9–30.

Izushi, H., Aoyama, Y., 2013. Evolution of country-Specific demand preferences and international leadership. In: Case of the Video Game Industry, Paper Presented at the Conference on Changes in the Industry Leadership and Catch-up Cycles, Seoul Korea.

Kang, H., Song, J., 2017. Innovation and recurring shifts in industrial Leadership:Three phases of change and persistence in the camera industry. Res. Policy 46, 376–387.

Katz, J., 1995. Domestic technology generation in less developed countries: a review of research findings. buenos aires, Argentina, IDB/ECLA. Res. Prog. Sci.Technol.

Kim, L., 1997. Imitation to Innovation: the Dynamics of Korea's Technological Learning. Harvard Business School Press, Boston.

Kim, Y.-Z., Lee, K., 2008. Sectoral innovation system and a technological catch-up: the case of the capital goods industry in korea. Global Econ. Rev. 37, 135–155.

Lall, S., 2001. Competitiveness indices and developing countries: an economic evaluation of the global competitiveness report. World Dev. 29, 1501–1525.

Landini, F., Lee, K., Malerba, F., 2017. A history friendly model of the successive changes in industrial leadership and catch-up by the latecomers. Res. Policy 46, 431–446.

Lee, K., 2013. Schumpeterian Analysis of Economic Catch-up: Knowledge, Path-creation and the Middle Income Trap. Cambridge Univ Press, Cambridge.

Lee, K., He, X., 2009. The capability of the samsung group in project execution and vertical integration created in Korea, replicated in China. Asian Bus. Manage. 8, 277–299.

Lee, K., Ki, J., 2017. Rise of latecomers and catch-up cycles in the world steel industry. Res. Policy 46, 365–375.

Lee, K., Lim, C., 2001. Technological regimes, catching-up and leapfrogging: findings from the Korean industries. Res. Policy 30, 459–483.

Lee, K., Mathews, J.A., 2012. South Korea and Taiwan. In: Amann, E., Cantwell, J. (Eds.), Innovative Firms in the Emerging Market Economies. Oxford University Press, pp. 223–248.

Lee, K., Lim, C., Song, W., 2005. Emerging digital technology as a window of opportunity and technological leapfrogging: catch-up in digital TV by the korean firms. Int. J. Technol. Manage. 29, 40–63.

Lee, K., Mani, S., Mu, Q., 2012. Explaining divergent stories of catch-up in the telecommunication equipment industry in Brazil, China, India, and korea. In: Malerba, F., Nelson, R. (Eds.), Economic Development As a Learning Process: Variation Across Sectoral Systems. Oxford University Press, pp. 21–71.

Lee, K., Park, T.Y., Krishnan, R.T., 2014. Catching-up or leapfrogging in the indian IT service sector windows of opportunity, path-creating and moving up the value-chains. Dev. Policy Rev. 32, 495–518.

Lundvall, B.-Å., 1992. National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning. Pinter, London.

Malerba, F., 2002. Sectoral systems of innovation and production. Res. Policy 31, 247–264.

Malerba, F., 2004. Sectoral systems of innovation: concepts. In: Issues and analyses of six major sectors in Europe. Cambridge University Press, New York, N.Y.

Malerba, F., Adams, P., 2013. Sectoral systems of innovation. In: Dodgson, M., Gann, D., Phillips, N. (Eds.), Oxford Handbook of Innovation Management. Oxford University Press, Oxford, pp. 183–203.

Malerba, F., Mani, S., 2009. Sectoral Systems of Innovation and Production in Developing Countries: Actors, Structure and Evolution. Edward Elgar Publishing Incorporated, Cheltenham.

Malerba, F., Nelson, R.R., 2011. Learning and catching up in different sectoral systems: evidence from six industries. Ind. Corp. Change 20 (6), 1645–1675.

Malerba, F., Nelson, R.R., 2012. Economic Development as a Learning Process: Variation Across Sectoral Systems. Edward Elgar Publishing Incorporated, Cheltenham.

Mani, S., 2005. The dragon vs the elephant: comparative analysis of innovation capability in the telecom industry of China and India. Econ. Polit. Week. 40, 4271–4283.

Mani, S., 2007. Keeping pace with globalisation: innovation capability in korea's telecommunications equipment industry. In: Mahlich, J.C., Pascha, W. (Eds.), Innovation and Technology in Korea. Physica-Verlag HD, Heidelberg, pp. 255–286.
Mani, S., 2013. Changing leadership in IT Services, Emergence of India as the Current World Leader in IT Services, paper presented at the Asialics 2013, Tokyo Japan.
Mathews, J.A., 2002. Competitive advantages of the latecomer firm: a resource-based account of industrial catch-up strategies. Asia Pac. J. Manage. 19, 467–488.
Mathews, J.A., 2005. Strategy and the crystal cycle. Calif. Manage. Rev. 47, 6–31.
Morrison, A., Rabellotti, R., 2017. Gradual catch up and enduring leadership in the global wine industry. Res. Policy 46, 417–430.
Mowery, D.C., Nelson, R.R., 1999. Sources of Industrial Leadership: Studies of Seven Industries. Cambridge University Press, Cambridge.
Mu, Q., Lee, K., 2005. Knowledge diffusion, market segmentation and technological catch-up: the case of the telecommunication industry in China. Res. Policy 34, 759–783.
Nakamura, T., Ohashi, H., 2008. Effects of technology adoption on productivity and industry growth. J. Ind. Econ. 56, 470–499.
Nelson, R.R., 1993. National Innovation Systems: A Comparative Analysis. Oxford University Press, Oxford.
Nelson, R.R., 1994. The coevolution of technology, industrial structure and supporting institutions. Ind. Corp. Change. 3 (1), 47–63.
Nelson, R.R., Winter, S., 1982. An Evolutionary Theory of Economic Change. Harvard University Press, Cambridge, MA.
Perez, C., Soete, L., 1988. Catching-up in technology: entry barriers and windows of opportunity. In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds.), Technical Change and Economic Theory. Pinter Publishers, London, pp. 458–479.
Posner, M.V., 1961. International Trade and Technical Change, vol 13. Oxford Economic Papers, pp. 323–341.
Shin, J.-S., 2017. Dynamic catch-up strategy, capability expansion and changing windows of opportunity in the memory industry. Res. Policy 46, 404–416.
Tushman, M.L., Anderson, P., 1986. Technological discontinuities and organizational environments. Adm. Sci. Q. 31, 439–465.
Vértesy, D., 2017. Preconditions, windows of opportunity and innovation strategies: successive leadership changes in the regional jet industry. Res. Policy 46, 388–403.
Vernon, R., 1966. International investment and international trade in the product cycle. Q. J. Econ. 80, 190–207.
World Bank, 2012. 'Exploring the middle-Income-Trap', world bank east asia pacific economic update: robust recovery. Rising Risks 2 (Washington, DC: The World Bank).
Yonekura, S., 1994. The japanese iron and steel industry. In: Continuity and Discontinuity. St Martin's Press, New York, pp. 1850–1990.
Yu, J., Malerba, F., Adams, P., Zhang, Y., 2016. Related yet diverging sectoral systems: telecommunications equipment and semiconductors in China. Ind. Innovation (forthcoming).