Forthcoming in *Industrial and Corporate Change*

An evolutionary perspective on economic catch-up by latecomers

August 2020

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An earlier version of this paper has been presented at the 2019 ICC-Tsinghua University Conference in Beijing. The authors would like to thank Richard Nelson, Giovanni Dosi, the conference participants and the referees of this journal for comments and feedbacks. The second author acknowledges the support by the Laboratory Program for Korean Studies through the Ministry of Education of the Republic of Korea and the Korean Studies Promotion Service of the Academy of Korean Studies (AKS-2018LAB-1250001).

ABSTRACT

This paper proposes an evolutionary view of economic catch-up, considered as a long-run process of closing the gap in capabilities by promoting learning and innovation in interaction with innovation systems (national, sectoral or regional). According to this perspective, catch-up is viewed as a dynamic evolutionary process which is not deterministic and cannot be planned in details, because it faces uncertainty and continuous change, is associated with a variety of exogenous events (windows of opportunity) and is the result of the idiosyncratic behavior of heterogeneous actors characterized by different understanding, views and experiences. This leads to a variety of responses and strategies by latecomer firms and countries, even in the presence of similar external technological or market conditions. One major point that emerges from this perspective is there is a strong complementarity between learning and capabilities by domestic firms and the national, sectoral, and regional systems in which firms operate. The paper also discusses various strategies, such as detours and leapfrogging, along the various stages and the different paths and trajectories that this long-term evolutionary process of countries and sectors follows.

1. Introduction

The economic rise of developing economies began after the World War II or after their liberation and independence. While the story is uneven, the initial success was by the four Asian tigers of Korea, Taiwan, Hong Kong, and Singapore. The second wave includes the stunning rise of China, followed by several East Asian or Latin American countries, however with less success (Nayyar 2019). If in the literature economic catch-up is defined as a narrowing of a latecomer firm's or country's gap vis-à-vis a leading country or firm (Fagerberg and Godinho 2005), recent contributions by Malerba and Nelson (2011), Lee (2013a) and Lee and Malerba (2018) propose that catch-up by latecomers does not mean just the act of cloning, but often the creation of divergent trajectories compared to the ones of leading firms or countries.

This is a fundamental distinction. If cloning is indeed present early on in the catch-up process, and becoming familiar with what firms at the frontier are doing characterizes the first stages of catching up, successful catch-up at later stages may involve doing things in a different way compared to the leading firms or countries. This difference results from the fact that exact copying is almost impossible in practice, because knowledge is not completely codifiable and transferable, and modifications and adaptations to local conditions are necessary. But most of all, because catch-up involves learning which leads to changes and modifications to existing products, processes and technologies, with the opening up of new trajectories of advancements.

This issue of cloning vs. divergence can also be considered in terms of imitation vs. innovation (Kim 1997), and is one of the most fundamental questions facing latecomers in their effort to catch-up. This view of catch-up can also be seen from the evolution of the literature. While the traditional literature, such as Lall (2000), Westphal, et al. (1985), and Hobday (1995), observed that latecomers tried to catch-up with advanced countries by assimilating and adapting incumbents' more-or-less obsolete technology, a new and contrasting view (see, among others, Lee and Lim (2001), Malerba and Nelson (2011) and Lee (2013a; 2019), is that latecomers do not simply follow the advanced countries' path of technological development; rather, they sometimes do something new, skip certain stages or even create their own path that is different from those of the forerunners.

Along these lines, and until today, there has been an accumulation of an extremely rich variety of contributions on economic catch-up by latecomers. These contributions had different focus, either on firms, or on countries or on sectors and technologies. Broadly, one strand of the literature focuses on catch-up as a learning and capability building process, which may take

a long time and that may require the mastery of a wide range of capabilities (Bell, 1984; Bell and Pavitt 1993). The other strand focuses on catch-up as affected by the effectiveness of surrounding innovation systems which refers to the relationship among the key actors involved in innovation activities (Freeman, 1987; Lundvall 1992; Nelson 1993). Both strands belong to a large extent to an evolutionary perspective on innovation and economic change, which emphasizes the evolutionary process of variety creation and selection taking place in industries and the economy, and which sees latecomer firms as heterogeneous agents going through dynamic process of learning in the context of diverse innovation systems (Nelson and Winter 1982; Dosi et al 1988; Nelson et al. 2018).

Drawing from and integrating all this literature, this paper offers an evolutionary perspective of catch-up by latecomers. Figure 1 illustrates the main theoretical blocks of such perspective. This perspective views catch-up as an evolutionary process that cannot be planned in any detail, and has lots of failures and false starts, which can and need to be understood and evaluated ex-post. At the same time, the learning and the capability accumulation by firms take place in innovation systems which include all the actors (firms and non-firms) involved in learning and innovation, the relationships among these actors and the institutions that shape and support learning and innovation (Freeman, 1987; Lundvall 1992; Nelson 1993). Therefore learning, capability building and catch-up by domestic firms depend greatly upon the nature and features of innovation systems, given the heterogeneous nature of the knowledge base, the specificity of the national, sectoral and regional contexts and the role of institutions in which innovative activities occur. In this setting, there is ample room for public policy because there is a high degree of not only market failure but, more importantly, also of capability and system failures (Malerba, 2009; Dodgson et al 2011; Lee 2013b).

In sum, the evolutionary view considers economic catch-up by latecomers as a process of closing the gap in capabilities (of firms and nations). This process however is not deterministic as it takes place in uncertain and changing environments and depends both on exogenous events (such as windows of opportunities, in terms of disruptive shifts or institutional changes) and endogenous processes of generation of, and responses to, change. This evolutionary process of catching up unfolds over a long period of time. Most of the time catch-up means finding niches and sectoral specialization because latecomer firms are late entrants in the already-established international division of labor (Mathews 2002). Such niche identification and specialization emerge over time because at an initial stage the process usually starts from imitating the leading countries and firms or from low-end product segments.

However, in the long term, successful catch-up requires not only the gradual enhancement of capabilities but also sometimes a radical jump or leapfrogging which takes advantage of diverse windows of market or technological opportunities (Perez and Soete 1988; Lee and Malerba 2017). Because this evolutionary process of national level catch-up at the country level has been uneven across industrial sectors, it unfolds to a considerable extent at the sectoral level, with sectors that vary significantly in terms of the conditions required to spur successful catch-up. Viewing the process of economic catch-up only at the aggregate level obscures this important fact. Therefore, this evolutionary perspective on catch-up starts from the basic premise is that economic catch-up should be studied at several levels, such as the firm, sector, region, and national-levels.

Figure 1 summarizes the main points of the paper and highlights main dimensions and variables of the framework discussed in this article.

[Figure 1 here]

In section 2 we first provide a brief overview of the evolutionary view of economic catch-up by latecomers. Then Section 3 concentrates on firms learning and capability building by latecomer firms, while Section 4 moves to the role of national and sectoral innovation systems. Section 5 provides a dynamic long-term evolutionary view of catch-up, both at the country and the sectoral level, and then discusses diverse sectoral dynamics. Section 6 concludes the paper with a summary and some final remarks.

2. Catch-up as an evolutionary process of learning and capability building in innovation systems

The evolutionary view of catch-up has roots in some classic works on economic development that go back to the 1950s and 1960s and examine the problems and bottlenecks that developing countries face in their efforts to reach some satisfactory level of economic growth and industrial competitiveness. In particular, three key intellectual giants can be mentioned. One is Raul Prebisch (1950) and the structuralist and dependency theory school, who point out that the periphery cannot continue to produce primary commodities, nor has to fully emulate the model of the advanced countries. Rather it has to find its own specific of mix of industrialization and specialization, with cooperation among developing countries. The

other is Albert Hirschman (1958) in his claim that economic development requires unbalanced growth in which pressures, tensions and disequilibria play a prominent role. In his view, the creation of backward and forward linkages and of broader interdependencies are necessary for the take-off. And finally, Gunnar Myrdal (1968) with his emphasis on the integration of economic, social and political dimension in the analysis of economic development. In this context, institutions and education play a key role in setting in motion a circular and cumulative causation.

More recently, Christopher Freeman (2019) has greatly advanced the discussion on these issues by proposing that economic development is driven by five subsystems with their specific historical processes: science, technology, economy, politics and general culture. These sub-systems are relatively autonomous but at the same time they interact and co-evolve. Positive congruence among them may provide a major spur to economic growth, while the lack of congruence may block or hamper growth. Along the lines of Freeman, Lundvall (2016) has focused on the extensive presence of developed innovation systems in successful economic development, and the lack of effective systems in underdevelopment; Fagerberg (1994) on the key role of technology in economic growth and competitiveness, Reinert (2007) on the positive dynamics brought by developing countries' internal development coupled by the increasing economic diversity and value added; and Cimoli, Dosi and Sitglitz (2009) on the central place of capabilities accumulation in industrial development.

Within this broad discussion, the specific analysis of catch-up has a long intellectual history going back to the pioneering work of Gerschenkron (1962). In his book, "Economic backwardness in historical perspective," Gerschenkron describes the economic catch-up of continental Europe in the late 19th century, with the United Kingdom as the forerunning country. Later on, it is with Abramovitz (1986) "Catching-up, Forging ahead and Falling behind" that the concept of catch-up has become standard vocabulary in the economic development literature (Lee and Malerba 2018). Since then, a very rich, various and heterogeneous literature has laid the foundations of the evolutionary perspective on catch-up presented in this paper.

Starting form this set of contributions, we propose that the core of an evolutionary view of catch-up is composed by three key elements: learning and capability building, institutions and innovation systems and a catching-up process that has to be examined in the long-term.

2.1 Learning and capability building

The evolutionary approach sees learning by firms not as an automatic transfer of foreign technologies but rather as highly uncertain process of search which follows different trajectories of incremental improvements and modifications (Nelson and Winter, 1982, Malerba, 1992). In this evolutionary process, knowledge is continuously transmitted, absorbed and generated. Knowledge has some basic characteristics of imperfect imitability and tacitness, that affect the ease of technology transfer (Winter, 1987). In turn, knowledge may refer to the various domains that are relevant for catch-up: technological, organizational and market knowledge. Because in an evolutionary perspective latecomer firms are boundedly rational actors that learn over time in a very idiosyncratic way (Dosi and Nelson, 2018), over time a great heterogeneity across firms along many dimensions emerges and persists.

Knowledge and learning are closely related to innovation in the sense of Schumpeter (1911, 1934), which represents a key factor for a successful catch-up. However, in a Schumpeterian fashion, innovations do not include only technological ones, but also organizational, marketing and institutional innovations. Innovation is a major source of variety generation in technologies and industries and is a driver of the industrial dynamics in latecomer countries. And evolutionary theory stresses the presence of technological paradigms and trajectories (Dosi, 1982), which prove very relevant when catching up and leapfrogging are examined.

This evolutionary view of learning, knowledge and innovation is linked to a capability view of catch-up. Here progress has been relevant on many fronts. The pioneering works by Katz (1984; 2001), Bell (1984) and Bell and Pavitt (1993) have discussed the role of learning and appropriate technologies for economic development; Cooper (1973) has pointed out the role of science and technology; Lall (1992; 2000) has stressed the variety of technological capabilities needed to catch-up and the role of public policy; Kim (1997) has analyzed the link between imitation and innovation in the process of catching up. All these developments are closely linked to a parallel development in the theory of the firm and in management literature (Penrose, 1959; Leonard-Barton, 1992; Helfat, 2018) that has introduced the concept of absorptive capacity (Cohen and Levinthal, 1989), organizational capabilities (Nelson and Winter, 1982), and dynamic capabilities (Teece et al. 1997 and Teece, 2012). In particular, Helfat and Peteraf (2003) have proposed the concept of capability life cycle, which identifies general patterns and paths in the evolution of organizational capabilities over time, and link the founding, development, and maturity of capabilities in a manner that helps to explain the sources of heterogeneity in organizational capabilities.

2.2 Institutions and innovation systems

Learning and capability building at the firm level are strongly affected by the context in which firms operate in terms of innovation systems, composed by a variety of actors and institutions (Freeman, 1987; Lundvall, 2017). This relationship in turn determines the economic performance of firms and of the whole economy. Innovation systems means that in their process of catching up, firms are supported by a variety of different actors, such as suppliers, users and consumers, universities, public research laboratories, government and financial organizations, and by institutions. The educational system proves to be a key element in stimulating learning and creating advanced human capital (Nelson, 1993). Universities and public research organizations also play a key role in catching-up because they do basic and applied research and supply advanced human capital (Mazzoleni and Nelson, 2007). Financial organizations (such as banks, stock markets as well as internal funding) are major sources of support for technology diffusion, innovation and catching-up. Vertical linkages with suppliers and users may provide catching-up firms with inputs and the relevant knowledge and information for production and innovation (Lundvall, 1988, Von Hippel 1988). The government and public policy may foster the diffusion of knowledge and support and direct the efforts of private firms in a systemic and forward looking way (Freeman, 1987; Fransman, 1985). This is done in a variety of ways by supporting basic research, the educational system, firms industrial R&D, specific sectors, entrepreneurship and regulation (Kim, 1997; Amsden, and Chu, 2003; Breznitz, 2007; Cimoli et al. 2011).

Institutions and firms and non-firm actors are part of different types of innovation systems. One is the national innovation system (Lundvall, 2017). According to this view, catch-up is highly affected by the broad set of national actors and institutions (Freeman, 1987; Nelson, 1993) and by the interaction and relationships among all the elements (Lundvall, 1992) that constitute the national innovation system. A great variety of types of national innovation systems exist across catching up countries, with different set of structures, relationships and capabilities of the actors that compose the system (Lundvall, 2016)

Because catch-up takes place at the industry level, and involves the specialization of countries in specific sectors, another innovation system context which proves extremely relevant is the sectoral one (Malerba, 2002). A sectoral system framework considers the sector as a system, and focuses on the knowledge underpinning innovation and production, firms' learning and capabilities, the other non-firm actors involved in innovation and production and the institutions – broadly defined- that characterize a sector (Malerba, 2002, 2004). There are

major differences in the patterns of learning and innovative activities across sectors, as shown by the Pavitt taxonomy (Pavitt, 1984) as well as in the sectoral systems and in the role of institutions. And there is ample evidence that the sectoral system dimension proves quite important in the explanation of the differences in the catching-up processes among countries (Mowery and Nelson, 1999; Malerba, 2004; Malerba and Mani, 2009; Malerba and Nelson, 2012; Lee, 2013a).

A third type of innovation system- clusters and regional systems- is also relevant in catch-up. Like other variants of innovation system, regional innovation systems consist of three core elements, such as actors, network and institutions, and reflect the long-standing interest on why innovation activities and economic development are unevenly distributed over space (Asheim et al., 2019: 1). Some of the earlier works that conceptualize and illustrate the regional innovation systems include those of Cooke (1992; 2001) and Asheim (1999). Here the intense formal and informal interactions take place at the local level with intense mobility of people and skills, so that knowledge transmission and sharing, and innovative division of labor become quite effective (Giuliani et al. 2005; Niosi 2012). The sources of learning of latecomer regions have been the focus of studies on East Asia and Latin America. For instance, Hu (2011) analyzes the long-term evolution of Hsinchu science park city in Taiwan on the basis of backward and forward patent citations to identify the countries from which Hsinchu has been learning, as well as the countries to which Hsinchu's knowledge has flown; Giuliani et al. (2005) examine upgrading and catching by Latin America clusters, while Cassiolato et al (2000) focus on the role of local systems in the Mercosur countries.

2.3 Catch-up as a long-term evolutionary process

Catch-up is an evolutionary process of variety creation, selection and retention (Nelson and Winter 1982) that unfolds over time through innovation, economic change and industrial transformation (Nelson et al. 2018, Malerba et al. 2016). This process cannot be planned in detail, because the actors involved in this process face uncertainty and continuous changes. These changes modify the conditions of what is viable and profitable: some economic actors see these changes and implications and act accordingly (however with their limited knowledge and understanding), while others do not. In this context, the role of dynamic capabilities (i.e. the ability to learn from and master change), may prove particularly important for maintaining a sustained catch-up process (Teece et al. 1997).

In this evolutionary process technological change affects the evolution of catching up firms, but in turns is affected by the capabilities, behavior and strategies of these firms. The same can be said for demand and user as well as for institutions (Pyka et al 2018; Murman, 2003). Responses and feedbacks play a major role in the catch up process, as do the mismatches among elements of the innovation systems. (Perez and Soete, 1988; Freeman, 2019). The results of this co-evolutionary process generate specific trajectories of catch-up, forging ahead or falling behind, the specialization of countries in particular sectors and the emergence of specific industrial and institutional settings in the countries and sectors.

One general point that is strongly associated to this evolutionary view of catch-up is the non-full predictability of catch-up, nor the possibility of understanding successful catch-up by only looking at the initial triggering moment and the final one. This long-term process implies a historical view of catch-up that pays attention to the path dependent sequence of events related one to the other that have lead to catch-up or that have blocked its successful dynamics. In the next pages we will examine these three broad issues more in depth.

3. Learning and capability building

3.1. Who are the latecomer firms

The acquisition of initial resources and capabilities by latecomer firms is of crucial importance. In this context, firms from emerging economies are often defined as "resource-poor late entrants" (Mathews 2002). The aspect of 'resource-poor' implies that one of the most fundamental differences between firms in the advanced and in developing economies is that the former have diverse resources available internally, from other firms or from the context, whereas the latter do not have all these critical resources. Another aspect has to do with the time of entry by latecomer firms in the global economy. These firms are late entrants in the sense that when they begin their manufacturing or service activities, the value chain of production may be already well established in the market segment they enter, and occupied by firms from advanced countries or other developing countries (Ernst and Guerrieri, 1998; Sturgeon and Gereffi, 2009; Lee and Gereffi, 2020). Given their late entry, latecomer firms have no choice but to inherit some segments left free from the firms from the advanced economies or to start from a position of original equipment manufacturing (Romijn, 1999; Amsden, 1989; Hobday, 1995).

As a resource-poor late entrant, the main task for a latecomer firm is not only to learn how to utilize existing resources effectively but also, and more importantly, how to acquire the

critically lacking resources and improve their availability over the course of the firm's life (Lee and Temesgen 2009). Profits are sought not just to be distributed back to the owners of the firm but to be used for further expansion of the firm's resources and to increase the capabilities of workers, build the R&D team, develop brand power and so on. In fact developing countries firms are faced with more imperfections in the markets and other constraints in the business environment (Tybout 2000, World Bank 2005; Lee 2013a).

Diverse are the resources that affect firm performance and growth: they include social capital (networks and connections), physical capital, human capital (embodied in workers employed by the firm), managerial capital, R&D capital (capability to conduct R&D independently), and brand capital. Lee and Temesgen (2009) indicate that for firms with low levels of capabilities in developing countries, growth is mainly due to relatively basic resources such as physical capital and basic human capital, whereas for the high-growth capability firms in developing countries, growth is more driven by higher level resources such as managerial capital and R&D capital.

Firms active in latecomer countries can be of different types. Multinational enterprises (MNE) and FDI (foreign direct investments) firms often constitute a key part of market structure in these countries. Whereas FDI may benefit local firms and the local economy by bringing in new knowledge acquired through imitation and learning (Findlay 1978, Blomstrom 1986), by facilitating human capital mobility (Fosfuri et al. 2001), and by promoting vertical linkages (Rodriguez-Clare 1996), these positive effects of FDI are often not confirmed by the empirical analysis (Gorg and Greenaway 2003; Aitken and Harrison 1999) because the transfer of knowledge may be limited or learning is not really automatic. Actually, FDI may bring in competition in the local market that destroys local learning and the accumulation of domestic capabilities. In this respect it has been found that FDI contribute to economic growth only when a sufficient absorptive capacity and orientation toward learning by domestic firms is available in the host country (Borensztein et al.,1998). Otherwise, it may only lead to jobs without any impact to the long term process of sustained catch-up.

In several developing countries, catch-up by domestic firms is initiated by big businesses, some of them state-owned enterprises (as in the case of several firms in China) that diversify into new activities and products. Having started often in simple labor-intensive sectors, when entering in new, capital-intensive industries these late-comer firms face severe barriers to entry (Chandler, 1990). In the 1990s in the absence of proprietary technology to be exploited in related industries, the pattern of diversification by these large domestic firms tended to be in

the area of key sectors identified the government's industrial policy (Amsden and Hikino, 1994). Through repeated, often unrelated, diversification, these firms (often in the form of business groups), have been able to learn and accumulate technological knowledge and project execution capability.

Thus, in many latecomer countries, catch-up is driven by big businesses or business groups (Kock and Guillen 2001; Guillen 2000; Amsden and Hikono 1994; Lee 2019) which utilize their own unique capability or resources in diverse areas. The advantages of being a member firm of the conglomerates or business groups has been discussed in the context of market failures (Leff 1978) or "institutional voids" (Khanna and Palepu 1997; 2000). Diversified groups have a superior access to capital markets. In labor markets, given the lack of well-trained business people and educational facilities, the groups can create value by developing able managers, and can spread the fixed costs of professional development over the various businesses within the group. From the view of the resource-based view, an obvious advantage of conglomerates is sharing and coordinating the use of scarce resources (Chang and Hong 2000).

However, in typical latecomer countries, the majority of domestic firms is composed by small firms. The motives for establishing a new firm in emerging countries and the barriers to entry and obstacles they face in their initial activities might look similar to the ones in advanced countries. In emerging countries however, new firms have the additional problems of lack of necessary skills and resources, often an inadequate infrastructure and the competition of multinationals from advanced countries that frequently preempt the market (OECD, 2016). So, survival and growth may be very difficult for new firms. Therefore, often these new entrepreneurial firms emerge, survive and grow because there are entrepreneurs that launch new companies into niche segments of the domestic market (Malerba et al. 2017; Li et al, 2019). However, the vast majority of new small firms in developing countries never expand, due to entrepreneur features, firm characteristics, relational and contextual factors (Nichter and Goldmark, 2009). In this respect some studies pay attention to the relationship between entrepreneurial attributes, firm characteristics and growth in developing countries (Bigsten and Gebreeyesus, 2007; Goedhuys and Sleuwaegen, 2010). According to this perspective, initially the technological capabilities of new small firms are not developed and are limited to a small range of domains (Molina and Malerba 2018). Only few of the new entrepreneurial firms are able to rise to domestic or international leadership due to continuous learning, capability accumulation and the appropriate strategies (Malerba et al., 2017).

3.2. Strategies of learning along the stages of development

In an evolutionary framework, R&D and deliberate learning not associated with R&D represent the two basic learning processes by which catch-up firms accumulate capabilities over time. The second type of learning, associated to tacit knowledge and skills, is particularly relevant in new small firms that do not have an R&D laboratory or a marketing department (Molina and Malerba, 2018). Both types of learning allow latecomer firms to develop basic competences and absorptive capabilities (Cohen and Levinthal, 1989) and to build over time technological competences (Figuereido, 2003).

Another learning activity takes place through exporting, because exporting is a way to learn from foreign buyers in the forms of feedbacks on blueprint, designs, quality control, and technical advice (Dahlman et al. 1985; Rhee, et al 1984; Jung and Lee 2010). In general, export orientation has been found to be the most important strategy for firm growth, compared to other strategies such as networking or integration strategies (including FDI, subcontracting, and connection with government) (Lee and Temesgen, 2009).

A different learning activity concerns the requirements of local demand and the interaction with domestic customers in the various market segments (Malerba et al. 2017). In some cases, in fact, segmented domestic markets have provided a nurturing environment in peripheral markets for the survival of domestic firms that had a low level of capabilities (Mu and Lee 2005; Li et al. 2019).

At the early stage of learning, a flexible IPR protection is important and allows imitation before going to later stages of innovation (Cimoli et al 2009). A large volume of literature tends to represent patents as providing incentives and protection to innovation. From a catch-up perspective, this view entails two problems. The first is whether or not patents are the most appropriate measures of innovation for latecomer developing economies where the capability of firms is too weak to generate innovations, and thus firms often tend to produce minor, adaptive, or non-patentable innovations. The second is whether the provision of stronger IPR protection (including patent protection) can lead to more innovation, especially in developing economies, where firms usually do not have pre-existing innovation capabilities (referred to as a capability failure in Lee 2013b). An alternative path is that of the so-called imitation to innovation detour providing a lower level of IPR protection to encourage minor innovations in the form of petit patents or trademarks during the transition stages (Lee 2019).

The specific strategies of learning are associated with the stages of development. A classical sequence is the one from imitation to innovation (see Figure 1). Kim (1997) proposes the three stages of duplicative imitation, creative imitation and innovation. Another one is the OEM-ODM-OBM stages (Hobday 1995).[1] The path from OEM to ODM to OBM is the standard upgrading process considered for the latecomer firms. However, there are limited cases of successful latecomer firms reaching the final stage of OBM, because there are several entry barriers to OBM (Chu, 2009). The transition to OBM status is not possible if a firm stays on the given path of subcontracting or collaboration, but only when a firm makes a structural break by adopting its own path-creation strategy, as exemplified by successful SMEs from Korea (Lee et al. 2015).

Another key issue for latecomer firms is how to integrate successfully within the global value chains (GVC) because one of the key factors of growth is getting connected to reliable international firms' pool of knowledge (Amsden,1989; Chang and Hong 2000) and acquire advanced foreign technologies from their suppliers and customers. In this respect, one may consider diverse strategies, such as networking with foreign buyer firms in exporting arrangement (export-orientation) or being a joint venture partner of foreign firms (Gereffi, 2018). However, as discussed by Morrison et al. (2008) entering into a stage of the global value chain will not automatically lead to innovation and better industrial performance. The risk is that latecomers might be trapped into those low-value-added positions of the GVC. Thus, Lee et al.(2018) proposed an "in-out-in-again" strategy: latecomers should first get into the GVC for learning purposes and then reduce the dependence on the GVC by increasing domestic value-added in the high-end segments. Eventually, latecomer firms might re-enter the GVC after developing those capabilities required for high-value-added activities. In Lee (2019), this non-linearity in GVC is termed as a detour of building domestic value chain before being fully integrated with GVC at later stages (see Figure 1). This detour in GVC is consistent with Mathews (2002) "linkage, leverage, learning", according to which latecomer firms should first establish linkages with established MNEs by targeting those "least rare", "most imitable", and

[1]. From original equipment manufacturing (OEM), a specific form of subcontracting under which a complete, finished product is made to the exact specifications of contracting firms, some firms evolve into own design manufacturing (ODM) firms, which carry out most of the stages of the GVC with detailed product design, while the customer firms of ODM companies continue to carry out marketing functions. The original brand manufacturing (OBM) firms on the other hand carry out manufacturing, design and R&D for materials, processing of products, and conduct sales efforts and distribution for their own brand.

"most transferable" resources. Then, they should leverage on the knowledge from these linkages and develop their own capabilities.

Two critical points have to be advanced when discussing these stages of development. First, often the issue is not just the sequentiality of domestic versus global chains but also the right balance of several channels and forces. For instance, Figueiredo and Cohen (2019) examine multiple external and internal learning mechanisms in innovative capability accumulation in pulp and paper industry in Brazil. Crossing the capability threshold to the world-leading level entails significant enhancement of absorptive capability and involves an openness to external knowledge acquisition (through interaction with local and international partners) and a combination of external learning with internal learning mechanisms. Relatedly, based on the extent to which latecomer firms rely on foreign technologies, Xiao, et al. (2013) propose four different types of strategies for latecomer firms, namely "dependent strategy", "imitative strategy", "defensive strategy", and "offensive strategy": the appropriateness of these strategies is contingent upon sectoral conditions (e.g., level of technology-intensity, effectiveness of IPR regime, availability of financing).

Second, catch-up is often the result of the right combination of technology and marketing strategies that are key for a successful catch-up over time (Malerba et al. 2017). For example, given an environment characterized by segmented markets and generational technological changes (such the one of mobile phones in China examined by Li et al, 2019), young domestic firms may focus first on a segment of the market that allows them to survive (such as a low-end market) by leveraging on their comparative advantages (Mu and Lee 2005). Later on generational technological changes open up windows of opportunities in new product segments. Because customers in the low-end market care more about the low price of the products, whereas customers in the high-end market care more about the quality of the products, domestic firms that successfully accumulate and upgrade their technological capabilities migrate from the low-end market to the high-end market. Relatedly, Kumaraswamy et al. (2012) find that latecomer firms often adapt their catch-up strategies from strategies that focus on sourcing technologies to strategies that focus on developing customer relationships.

4. The role of innovation systems in catching-up

In an evolutionary perspective it is not possible to gain a full understanding of the catch-up process if we limit the analysis only to a learning and capability perspective at the firm level.

It is necessary to pay attention also to the key role of the context and the environment - the innovation systems - that support firms in their catching up process. This is because an evolutionary approach sees firm growth and catching up as the interaction between firms' resources, and innovation systems, as composed by a variety of actors and institutions. These systems can be national, sectoral, technological or regional/local. Here progress has been significant. A lot of in-depth case studies have been complemented by quantitative work, such as Fagerberg et al. (2007, 2010) and Lee (2013a). The cases have been rich in details and have followed a historical perspective, while the quantitative analyses have increasingly used highly disaggregated longitudinal micro-level data. All these contributions have identified the presence of major heterogeneity at the country, sectoral, technological and regional/local levels. At the same time, however, parallel work has attempted to find stylized facts and patterns of catch-up and to identify similarities across countries, sectors and clusters. In the next sections we will focus on national innovation systems and sectoral systems.

4.1 National innovation systems and catch-up

At the country level, one of the strongest empirical evidences is that countries' technological capabilities and institutions affect catch-up (Lee and Lee 2019). Examining the growth of more than 100 countries, Fagerberg et al. (2007, 2010) and Fagerberg and Schrolec (2008) find that technological capabilities and national systems do affect the growth of GDP per capita, while unit labor cost and openness of the economy play a relatively minor role. Here national innovation systems, in terms of actors and institutions are considered in a broad way, both in terms of the actors and in terms of higher education, the legal system, norms, technological cooperation, public policy and so on. However they can also be measured by one composite index of NIS as in Lee and Lee (2019).

The discussion on national systems however has to take into account that system boundaries get increasingly blurred and that often technological innovation takes place in transnational contexts. As Binz and Truffer (2017) emphasize, in some dimensions the national context has to be substituted with the global and multi-locational ones, in particular for global demand and the generation of knowledge resources. In addition, often international networks and interrelated institutional structures and actors become very relevant in the innovation process (Fuenfschilling and Binz, 2018). Therefore, for latecomer firms, especially from those economies with a limited size of domestic markets, catch-up requires the development of

capabilities to tap into global dimensions and demand and to balance effectively the national and international aspects of innovation systems.

In addition, in a more globally interconnected world, the geography of production and the power relationships among different national systems has changed (Gereffi, 2014; 2018; Ahmad and Primi, 2017; World Bank, 2017, Primi and Toselli, 2020). With the exception of China, few developing economies have been able to associate upgrading and increased participation in GVC to processes of homegrown branding and creation of leading flagship companies (Primi and Toselli 2020). In fact, most of the increased participation of developing economies to GVC has taken place through increased absorption of foreign technology, capital and knowledge, therefore resulting in processes of deepening in assembly functions, associated with little (if not absent) home-grown branding creation processes (as in the case of automotive in Mexico and electronics in Vietnam).

A broad analysis of the role of national innovation systems, institutions and catch-up in Latin American, African and Asian countries can be found in Arocena and Sutz (2000), Cimoli et al. (2011), Malerba and Nelson (2012), Muchie and Baskaran (2013), Kim and Lee (2015), and Lundvall (2016). From all this work it is evident that the features and structure of national systems as they have emerged over time differ extensively across countries, so that "one type does not fit all". In particular, regarding the differences in NIS in East Asia versus Latin America, Kim and Lee (2015) point out that in the former policymakers preferred technology policy to science policy by putting emphasis on technological development in private industrial sectors, whereas in the latter policy makers focused on science rather than technology. Thus in the NISs of the latter there was an isolation of academia from the private sector and its technological activities: the science community and academia tended not to reflect industrial needs and was more oriented toward academic research. Econometric analysis by Kim and Lee (2015) find that it is not scientific knowledge per se but technological (or engineering) knowledge that is significantly related to economic growth in emerging economies, although good engineering is supported by good scientific knowledge. Generating scientific knowledge does not automatically lead to generating technological knowledge: it is an effective NIS the mechanism that translates and commercializes scientific knowledge into technological knowledge and thus into economic growth.

One of the key elements of a national innovation system is local demand (Malerba et al., 2017). With its specific characteristics, local demand may have different requirements with respect global demand and may create an environment sheltered from international competition

and in which domestic firms learn, survive and grow. Particularly when it is large (as in China, India and Brazil), domestic demand may trigger a virtuous cycle of learning, capability building and growth (Malerba et al. 2017). It is possible to identify two specific dimensions of local demand that start this mechanism. One is related to the presence of low-end markets, in which local firms provide low-price solutions and can benefit from economies of scale in production and marketing (Mu and Lee 2005; Li et al. 2019). This has been the case of auto in China or India or pharmaceuticals in India (Guo, 2017, Mani, 2017). The second is related to specific groups of users that require customized solutions which are different from the products offered by multinationals or by imports from advanced countries. This is the case of software in large countries such as Brazil (Araujo, 2017).

Another key element of a national innovation system is IPR. A strong IPR protection in advanced countries against the exports from catching-up economies may aggravate the difficulty of achieving innovation-based catch-up in latecomer countries (Lee 2019). Because the WTO regulates and provides guidelines for IPRs through the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement, developing countries had to increase their level of IPR protection to reduce the gap in the IPR protection level between developed and developing countries. Thus, many exporting firms in the developing world tend to incur high costs when adapting to TRIPS obligations: the strict enforcement of IPR laws in developed countries may curb the exports of developing countries to advanced countries because their exports are too imitative or are developed around existing products. The implication is that the negative impact of high levels of IPR protection in the North may be greater for rapidly catching-up developing countries than for low-income countries which command very low technological capabilities, show weak export performance, or exports that are arranged by inter-firm trade in the form of contract manufacturing and FDIs (Shin et al., 2016)

Finally, among the key elements of NSI, the government (national and regional) and public policy are ones of the most relevant for catch-up. In an analysis of the role of national innovation systems in Latin American, African and Asian cited in the previous pages institutions defined in a broad way have been shown to play major role in the process of catching-up and active public policy -rather than hands-offs policy- has emerged as necessary for growth and development.

More specifically, following the discussion in Landini and Malerba (2017) we can identify some broad types of intervention by the government to shape the NIS of a country. The first one is related to policies aimed at building up and strengthening domestic capabilities, in terms

of R&D support for domestic firms, promotion of joint-ventures and technological agreements, development of public programs for creating advanced human capital in science and engineering and establishment of public enterprises in key sectors or new technologies (Lall 1992, Cimoli et al., 2009, Malerba 2009, Lee 2013b). Many Asian countries (most notably South Korea) focussed on capability building as a key element of their catch-up strategy. However, the specific intervention associated with capability building may differ from country to country. In some cases (such as for instance in China) it supported the launching of large state-owned companies with the objective of compensating the lack of competitive private firms. In other cases (such as in South Korea) it combined licensing-based access to foreign competences with large investments in human capital (Lee, 2013b). In most cases the main effect of these interventions has been to reduce the capability gap that separated latecomer and incumbent firms.

Similarly to capability building, a second type of intervention has favoured firm learning, ranging from the development of a national research and information infrastructure, to the support of the diffusion of new technologies, to the improvement of the education system (Lundvall and Johnson, 1994; Metcalfe, 2005). Examples of such policies include the launch of development programs to spread firms' best practices as well as the removal of barriers to the mobility of skilled personnel between different kinds of organizations (Chaminade and Edquist, 2006).

A third type of policy is market protection with import tariffs, subsidies, and barriers against foreign direct investments. Lall (1992) suggests the need for latecomer countries to protect their emerging industries until domestic firms have accumulated sufficient capabilities to be competitive in international markets. Historically, the adoption of market protection has characterized the development process of several countries. Vernon (1989) and Chang (2005) argue that forms of market protectionism have been also used by every developed country in critical stages of industrialization, including UK and US. Finally, public policy has also promoted the entry of new domestic firms (Landini and Malerba, 2017), with the provision of publicly funded venture capital as well as incentives for the creation of start-ups (Rodrick, 2004).

4.2 Sectoral systems and catch-up

The catch-up in different sectors is supported by a set of different actors and institutions and may occur in different ways. These differences tend to be glossed over in the early writings

on NIS. This comes as a surprise because the catch-up of countries often is driven by some key sectors and these key sectors differ from country to country and have their own specificities. (Malerba, 2002; Malerba and Nelson, 2011). In the following pages we will concentrate on three key aspects of sectoral systems: the technological regime and knowledge context, the role of other non-firm actors, and the role of institutions.

The thesis that sectors differ from one another in terms of innovation patterns and learning modes has been at the base of the Pavitt taxonomy (Pavitt, 1984). Also major structural differences across sectors in market structure and in the actors and the environment that originates innovation has been has been one of the key ideas derived from the legacy of Joseph Schumpeter[2]. As a starting point, the evolutionary approach has identified two different types of sectors, a Schumpeter Mark I type of sector with small firms and high entry rates of new firms, and a Schumpeter Mark II type of sector with large firms and high industrial concentration (Malerba and Orsenigo, 1996). This difference is due to the working of different technological regimes and demand regimes (Malerba et al. 2016). In particular, the concept of the technological regime defines the particular knowledge environment where firm problem-solving activities take place (Winter 1984, Nelson and Winter, 1982, Malerba and Orsenigo, 1997). In particular, Breschi et al. (2000) measure technological regimes in terms of the four variables, such as technological opportunity, appropriability of innovations, cumulativeness of technological advances, and originality. Then, Park and Lee (2006) consider those aspects of the technological regime that are more relevant in the context of catching-up by emerging economies, including the cycle time of technologies, uncertainty, accessibility and the initial stock of knowledge.

In general, those elements of technological regimes relevant for catch-up can be grouped into two categories (Lee 2019). The first group of variables is related to the accessibility of a foreign knowledge base (degree of embodied technology transfer and modularity) that are highly important in the early (or entry) stage of technological catch-up. The higher the degree of embodied technology transfer in imported machinery, the easier it is for productivity to catch-up. Similarly, high modularity in sectors or technologies (Genba et al. 2005) allow ease and rapid technological catch-up because latecomers may enter the market through outsourcing the required components. The automobile industry is an example of an industry with a high level of embodied and modularized technology. Entering the automobile industry

[2] Although Schumpeter did not stress sectoral differences in his writings

as an assembler is not difficult as long as a latecomer finds suppliers of various parts and components. Similarly, due to the high degree of modularity, Chinese mobile phone producers have relied on core technology parts (e.g., main platforms and core software) from foreign suppliers and combined them with their own peripheral technologies during their entry in the early 2000s.

The second group includes such variables as tacitness of knowledge and cycle time of technologies that affect the speed of learning, which may prove more important in later stages of technological catch-up. Tacit knowledge means that some knowledge cannot be codified and cannot be learned quickly, but it can only be acquired through practice. Therefore, the transfer of knowledge among people, firms, or countries is slow, costly, and uncertain. As more tacit knowledge becomes necessary in the learning of a target, latecomer countries cannot easily catch-up with their advanced counterparts. By contrast, knowledge with high explicitness can be codified and learned easily. Jung and Lee (2010) have verified that those sectors that involve the extensive use of tacit knowledge, such as machine tools, achieve slow technological catch-up. And for the automobile industry the high degree of tacitness of knowledge makes the catch-up in later stages not easy.

In addition to the technological environment, in a sectoral system also the roles of institutions and non-firm actors, including universities, public research organizations, the government and financial organizations, are quite important. Universities and public research organizations have stood prominently for catch-up only in some industries, such as in the emergence and growth of the Indian pharmaceutical industry (Ramani and Guennif, 2012). On the contrary, public research laboratories have played a key role in sectors in which mission oriented public programs and major partnerships with private firms are important, such as in the catch-up in telecommunications of Korea and Taiwan (Lee et al., 2012; Mazzoleni and Nelson, 2007).

Also, because in general institutions and public policies have been relevant in catch-up (as discussed in the previous section), a sectoral system view adds s that this relevance has differed across industries (Malerba and Nelson, 2012). For example, in those industries based on science and research, as in pharmaceuticals, the support of universities has been a key factor for catch-up and upgrading (Rasiah et al., 2012). On the contrary, in industries in which large R&D projects and the technological regime is cumulative, as in telecommunications, successful public policy has supported the R&D of domestic firms and favored R&D consortia, as in the case of Korea and China (Lee et al., 2012). However, in those industries in which skills and new firms drive development and growth, such as software, public policy has supported skill

formation at various levels and the formation of new and small enterprises (Niosi et al., 2012). Finally where empirical knowledge is at the base of diffusion of advanced practices among many small and micro firms, such as in the agro-food sector, public policy has fostered a technological and scientific infrastructure, private-public partnerships in experimentation and the diffusion of market institutions, as in the case of Brazil, China, and Costa Rica (Gu et al., 2012).

In a system perspective, the various elements of a sectoral system display different complementarities needed for the catch-up in different industries (Malerba and Nelson, 2011). For example, in pharmaceuticals university research has been accompanied by a relaxation of IPRs so that new domestic firms could accumulate capabilities (Ramani and Guennif, 2012). In software system complementarities for catch-up have included intensive entrepreneurship and local clusters of small- and medium-sized firms with widespread links with advanced customers (Niosi et al., 2012), while in telecommunications, active government policies and standardization worked together with investments by large firms (Lee et al. 2012).

And in some industries the domestic structure of backward and forward linkages à la Hirschman across sectoral systems (Gonzales et al. 2019) have proved quite effective for catching-up. In the case of auto for example, these linkages have led to the rise and growth of an advanced domestic auto parts industry in several latecomer countries. It must be noted however that in some cases domestic vertical linkages may not prove effective even when a local upstream industry coexists in the same country with a local downstream industry. In fact, when the downstream domestic firms are highly exposed to international competition, they may end up not buying inputs from the local suppliers if these local suppliers are not advanced technologically. Because these downstream domestic firms face international competition, they need state-of the-art inputs, and these inputs have to be sourced globally and not locally, as in the case of Korean machine tools (Kim and Lee, 2009) and semiconductors and telecommunications in China (Yu et al. (2017).

5. Catch-up as an evolutionary process

Catch-up is an evolutionary process, in which the various actors involved have specific knowledge, face high uncertainty and go through adaptation and change. Therefore this process cannot be predicted in all the details but evolves through stages and may follow diverse path and trajectories. During this evolutionary process, variety generation in terms of products

and technologies takes place and niches and sectoral specialization emerge. In what follows, inspired by the discussion about national systems and sectoral systems in Section 4, we will discuss this process by looking at the long-term evolutionary process of countries and sectors as well as by discussing the dynamic modelling of such process.

5.1. The long-run evolutionary process at the country level

If we take a long run perspective, the historical experience shows that many developing countries initially face labor (or natural resource) abundance so that they become specialized in labor (or resource)-intensive sectors. Thus the capital–labor ratio becomes a key variable in sectoral specialization. In economies that are far behind the frontier of technological know-how and skills, and where labor is abundant and capital is scarce, market forces and traditions will generally support sectors that are labor intensive, and do not require high level of technological or business sophistication (Kuznets, 1966; Lin 2012).

Then, as capabilities develop, the next stage of economic development occurs as resources flow into sectors where capital intensity and labor productivity are higher. These industries may require a certain amount of technological know-how, skills, and managerial sophistication. Therefore, the choice among different capital intensive sectors may emerge as a difficult issue of decision making with an uncertain outcome. In other words, the simple criterion of capital-labor ratio no longer works because there are many capital intensive sectors and also because they tend to involve entry barriers which are higher than in labor intensive sectors. Further, typical middle income countries at the stage tend to face rising wage rates. Thus, many of these countries are stuck in the middle income trap. They are trapped in the middle between low-wage manufacturers and high-wage innovators, because their wage rates are too high to compete with low-wage exporters and the level of their technological capability is too low to compete with high income countries (Yusuf and Nabeshima 2009; World Bank 2010 and 2012).

Examples of countries that have suffered from the middle-income trap are Brazil and Argentina, whose growth has stalled during the 1980s and the 1990s. Other similar cases are Indonesia and Thailand. This trap is indeed related to bottlenecks or binding constraints (Rodrik 2006, Hausmann et al. 2008), but it is mainly due to the gap in innovation capabilities (Lee and Kim 2009) and the pressure of the international environment (including the WTO regime and IPR protection) fostered by the incumbent economies and firms (Shin et al 2016).

These conditions necessitate the latecomer to take several detours, eventually path-creating or leapfrogging (Lee 2019). The first detour is from imitation to innovation by arranging loose

IPR regime at the transition stage. It is necessary because too high IPR protection might suffocate the diffusion of knowledge and interfere with adaptive, follow-on, innovation. The second detour involves the in-out-in again sequence in terms of the GVC participation. It emphasizes promoting domestic value-added before an economy is fully coupled with GVCs. The third detour involves specializing in sectors corresponding to short cycle time of technologies (such as IT manufacturing or services) before entering long cycle sectors (such as science-based or pharmaceuticals). Short cycle sectors refer to sectors in which the particular knowledge and competences needed for innovation tend to changes periodically (Lee, 2013a; Park and Lee, 2006). Therefore, the advantages that firms at the frontier countries have because of their longer experience in the industry do not help them much when the frontier technology frequently changes, which means low entry barriers to latecomers. One situation that makes technologies short-cycled is the arrival of 'competence-destroying' innovation, proposed by Tushman and Anderson (1986). The technological development of the Asian tigers over the last three decades (Lee 2013a) reflects the increasing specialization of their industries into short-cycle technologies (such as ITs), which helped them to overcome the middle income trap around the mid to late 1980s. However, as economies reach technological maturity and develop a high level of capabilities (as Korea is doing since the 2000s), they have been switching to long-cycle technologies, such as bio-medical or pharmaceutical industries.

This sequence of imitation first, then building domestic value chains and finally entering into short cycle technologies is a suitable arrangement, although the outcome cannot be precisely predicted given the uncertainty surrounding this process. The final stage of catching-up is path-creation or leapfrogging, which involves latecomers not only catching up but also overtaking of the incumbent. Leapfrogging involves a latecomer doing something earlier than, or different from, the incumbents (Lee, 2019). It is different from a detour which mostly involves building capabilities. However just taking detours may not be sufficient to attain radical reversals of market shares and leadership changes. Such leapfrogging is similar to the "long jumps" (Hidalgo et al. 2007) that a latecomer economy must perform to shift themselves to product spaces located far from their current position or core spaces dominated by high-income economies. Leapfrogging face major uncertainty but can be facilitated when exogenous moments of disruption - called windows of opportunity- take place, as in the case of the arrival of new techno-economic paradigms or, in a narrow sense, of disruptive innovations (Perez and Soete 1988).

5.2 The long-run evolutionary process at the sectoral level

As mentioned above, the rise of a national economy is often associated with its success in a certain number of leading sectors (Freeman, 2019). Thus, achieving leadership and leapfrogging in some sectors is critical for a nation to rise beyond the middle-income status to become a high-income economy. In other words, the final stage of catch-up tends to involve rivalry for leadership with the incumbents in specific industries. Thus, in an evolutionary perspective, a country's catch-up means facing changes in technologies, capabilities and institutions with all the implications in terms of understanding what is viable and what is not in a specific sector. And an evolutionary view means that focusing only on the short run obscures dynamics and the changing picture of innovation and competition. For instance, in the mobile phone industry, Motorola invented the mobile phone. However, with the emergence of cell phones based on different standards (GSM digital technologies), Nokia gained control of the market. Then, in the era of smartphones, Samsung and Apple toppled Nokia (Giachetti and Marchi, 2017).

The long evolutionary changes in industrial leadership in which discontinuities, capabilities and innovation systems play a paramount role have been examined in terms of catch-up cycles in Lee and Malerba (2017; 2018). Here the focus has been on leading sectors in which the incumbent fails to maintain its superiority in terms of technology, production or marketing, and a latecomer catches up with the incumbent. Subsequently, that latecomer relinquishes its position to a new latecomer. The reasons of successive changes in industrial leadership have been typical of an evolutionary process: the combination of discontinuities in the sectoral system, the accumulation of domestic capabilities, the development of appropriate innovation systems and forceful responses to the discontinuity by the domestic firms, again with a lot of failures and with major uncertainty ex-ante about what was viable and what was not. These discontinuities in the dynamics of a sectoral system have been labelled 'windows of opportunity' by Lee and Malerba (2017). Lee and Malerba (2017) focus on three of them. One is a 'technological window' related to major changes in technologies. A second is a 'demand window' related to a new type of demand, a major increase in local demand, or a business cycle (in particular the arrival of a downswing in business cycle which creates difficulties for incumbents, whereas latecomers may have lower entry cost than in normal periods, Mathews, 2005). A third window of opportunity is an 'institutional/public policy window' related to a public intervention in the industry or a drastic change in institutional conditions. It must be

noted that some of these windows are not be exogenous, but emerge out of the evolution of the sector.

For a change in industrial leadership, these windows need to be met by an appropriate 'response' of the domestic firms and by an inadequate response by the incumbents and the surrounding innovation system (Lee and Malerba, 2017). Relatedly, with the opening of a window, the current leaders may lack an effective response due an 'incumbent trap' (Chandy and Tellis 2000; Lee and Ki 2017) together with system mis-alignments or inadequacies in the new context. This is because leading firms may have a different view of the relevance of the window and base their understanding on their previous experience in the old context. Therefore they tend to be complacent and entrenched with the current success. Moreover, also the sectoral system in which the current leaders are embedded into may not be able to change rapidly or to adapt fully to the new windows.

Actually, diverse cases of catch-up cycles in the long-run evolution of sectors have been examined, by Giachetti and Marchi (2017) on cell phones, Shin (2017) on the memory-chips, Kang and Song (2017) on cameras, Lee and Ki (2017) on steel, Vertesy (2017) on mid-sized jets, and Morrison and Rabellotti (2017) on wine. These cases show that due to uncertainty, diverse expectations and heterogeneous capabilities, quite different combinations of windows of opportunity and responses from both incumbents and latecomers may emerge. These combinations affect the specific trajectory of the sector, determining which pattern of successive catch-ups is most likely to emerge in a sector. While the above mentioned cases have adopted appreciative theorizing (Nelson and Winter 1982: 46) and provide a 'causal explanation' of the observed patterns of catch-up cycles in diverse sectors, another method of analysis regards the use of simulation models. To this method we turn in the next sub-section.

5.3. Modelling the long-run evolutionary process of catch-up

The strong empirical analysis on catch-up as an evolutionary process and the related appreciative theorizing has been complemented by modelling. Here one may find a developed tradition of evolutionary models within the technology gap literature in international trade, discussed for example in Dosi et al (1990).

More recently, history-friendly models of industry evolution (Malerba et al., 2016) have been used to examine countries and firms' catch-up. History-friendly models are evolutionary models which follow a very specific methodology and are based on the empirical analysis of specific dynamics and evolution and the related appreciative theorizing. In fact the modelling

and calibration process rely – in a highly qualitative way – on the evidence put forward by the empirical analyses of the specific industries and processes (Malerba et al., 2016), Therefore, these models are quite useful to explore in a rigorous and transparent way the factors proposed by the case studies of the catch-up of specific countries and firms. Examples of the use of these models are the analysis of the catch-up of Korea and Taiwan in DRAM memories (Kim and Lee, 2003) and of Germany with respect to Great Britain in the XIX century in synthetic dye industry (Brenner and Murmann, 2016) [3] Another example is the examination of the factors affecting the catch-up process in the long run in mobile phones and memory chips (Landini et al., 2017). Here the long-run analysis shows two leadership changes which are replicated by the model. Then the simulation analysis reveals that the more disruptive is the new technology and the lower are the incumbents' capabilities, the greater is the shake-up of market shares between the incumbents and the latecomers. In addition, a leadership change is more likely to occur when it coincides with certain responses to the window by the various actors, such as a high lock-in behaviour by the incumbents.

History-friendly model also have been used to examine the dynamics of the different stages of the catch-up process, as in Li et al. (2019) on the long march to catch-up by Chinese firms in the mobile communications industry. Here the sectoral environment in terms of segmented markets and generational technological change facilitated the catch-up of domestic firms with respect to foreign multinationals. Segmented markets provided a nurturing environment in peripheral markets for the survival of domestic firms (which started with low level capabilities in their infant stage), while generational technological change opened windows of opportunities for domestic firms to catch-up with foreign multinationals in new product segments. Segmented markets and generational technological change allowed domestic firms to leverage their initial advantages in peripheral markets to catch-up in core markets.

The use of counterfactuals in these models allows to assess the strengths of specific factors in shaping the process of catch-up compared to other competing explanations. For example, Brenner and Murman (2016) show that German firms came to dominate the global synthetic dye industry because of the high responsiveness of the German university system in terms of creation of advanced human capital (and not because of the high initial number of chemists in Germany at the start of the industry or the late introduction of a more narrow type of patent regime in Germany). Landini et al. (2017) show that depending on the size of the windows,

[3] In the synthetic dye industry German firms came to surpass British and France firms and to dominate the global synthetic dye industry for three decades before World War I

the degree of lock-in, the shape of technological landscape, and incumbents' average initial capabilities, different catch-up dynamics can emerge: an aborted cycle, a persistent leadership cycle, a two-waves cycle with the coming back of the incumbents and finally a coexistence of latecomers with incumbents. Finally, Li et al (2019) highlight that that the process of catch-up can be facilitated by the extent of the relatedness across technological generations.

Finally, for their characteristics, these models can be quite useful for a public policy discussion. For example, starting from the case of mobile phones, Landini and Malerba (2017) examine the effects of different public policies (such as strengthening capability building, favoring firms' learning, protectionism and support of entry of new domestic firms) on the success of the catch-up of a latecomer. They confirm that capability building and firms' learning are important drivers of catch-up, but they also find that when a large technological discontinuity takes place, policies that support entry of new firms favor catch-up while protectionism has the opposite effect. Protectionism favors catch-up only when no technological discontinuity opens up. Moreover, depending on the technological conditions, different policy complementarities may be set in motion.

5.4. Variety of Trajectories and Pathways for Catch-up

While most of the literature tends to emphasize the primacy of manufacturing in catching-up, stressing that no country has reached the high-income status without first developing manufacturing, it is our view that the manufacturing to service sequence is also just one of the options for latecomers. There exist alternatives, including leapfrogging into newly emerging sectors (new IT services), advanced resource-based sectors, combination of services and manufacturing taking advantage of the technologies of the new millennium, and green technologies (see Figure 1). This is because in an evolutionary perspective catch-up is not deterministic but a dynamically evolving process, always seeking new niches and taking advantage of new windows of opportunity associated with not only hard-core innovations but also new business models. In the next pages we examine some of the possible dynamics.

IT Services

One option of specialization for latecomer is not in manufacturing but in services. Here it is possible to identify several sectors, such as mobility, ecommerce, games, mobile payments, travel, music and entertainments, and other apps-based services. Success in services may have boosting effect on local manufacturing, given the emerging trend of blurred boundaries

between service and manufacturing. However, startups in these sectors have to seek niches unless there is market protection by the government against foreign firms. It is well-known that in China many of IT startups, which became later on giants (eg, Baidu, Alibaba and Tencent) were able to grow owing to asymmetric regulations against foreign firms (like Google, Amazon, Uber, and Facebooks).

The case of Indian leapfrogging into IT service may indicate the possibility of service-first leading to manufacturing later, as a development strategy. In services India has risen as a viable exporter accounting for more than half of its total exports, the highest ratio in the world. The earnings in convertible currency generated by such exports has become a basis for Indian promotion of manufacturing which requires imports of capital goods. Actually, Mani (2014) and Lee (2019) discuss the case of India as a prime example where the IT service industry is a leading growth engine. The first window of opportunity for India surfaced when a new techno-economic paradigm emerged, and the second when the government intervened by changing policies on foreign firms. Initially Indian IT service firms provided low value-added services, such as application development, maintenance, and testing. Eventually, they created their own unique path or business model in IT services and reinvented the offshoring model and later the global delivery model (GDM), which is now a global industry standard. This industry is currently led by three giants (TCS, Wipro, and Infosys), which competed successfully against advanced IT service firms in the US and the EU. Among the three leading IT firms, Wipro exhibited the most typical example of leapfrogging into the IT service industry, bypassing the IT manufacturing stage.

High value-added resource sectors

Natural resources industries represent key industries in which several countries, particularly in Latin America and Africa, have caught up or attempt to catch-up. These industries are characterized by geographic specificity and knowledge idiosyncrasy, and are often considered ‘low-tech’ industries. However, in-depth analysis of natural resource industries – such as the one in Figueiredo and Cohen (2019) - indicate that also in these industries catching up firms have advanced technological and market capabilities and that innovations are frequent. Actually, Lebdioui et al (2020) have observed that Malaysia and Chile are showing some signs of growth beyond the middle income trap owing to their success not in manufacturing but in several resource-based sectors (such as petroleum, rubber and palm oil sectors in Malaysia, and salmon, fruits, wine and forestry in Chile). In Malaysia, these resource-based industries have

shown great degrees of linkages, competitiveness and technological sophistication, notably through governmental support for R&D activities. This is in sharp contrast with the performance of Malaysian electronics and automotive which have become less successful in upgrading into higher end segments. In the case of four sectors in Chile, Lebdioui et al. (2020) show that industrial policy by the government has had a key role to play as a catalyst of human capital accumulation, a venture capitalist, a promoter of trade, and an ensurer of reputation through strong regulatory and quality control.

Given the geographically specific and idiosyncratic nature of their resource industries, firms cannot not just absorb or benchmark knowledge from leading incumbent firms. Thus, latecomer firms have to eventually develop their own distinct technologies which are suitable to the soil, climate conditions, and diseases of the specific natural resource industry. They often become engaged in unstructured in-house learning efforts which prove effective in creating the capabilities at the base of the emergence of new trajectories and path-creation catch-up (as discussed for natural resource industries in Brazil by Figueiredo and Cohen, 2019).

However, in these industries often the "resource curse" hypothesis proposed by Sachs and Warner (1995) and discussed among others by Katz (2006), Iizuka and Soete (2011) and Lundvall (2016) is present. Most of these authors have pointed out that, in contrast with the Nord European countries, which developed a competitive and diversified economy from a strong presence of natural resource, the reasons of failure to catch-up in several developing countries in Latin America or Africa is due to the fact that these countries had limited investments in knowledge and weak institutions that did not support the processes of learning, upgrading and diversification in related manufacturing and services (Lundvall, 2016). The case of Chilean salmon farming discussed by Iizuka and Katz (2011) indicates that countries that have natural resource industries need to develop a set of appropriate institutions that can monitor and manage the exploitation of the common pool of resources under conditions of long term sustainability and that can maintain close and effective interactions with the natural resource industries in order to foster environmental sustainability.

Opportunities for Green Development and for the New Technologies of the Third Millennium

Two broad groups of sectors and technologies that may represent new opportunities for latecomer firms and countries are the green technologies and other new technologies of the beginning of the third millennium. We will briefly discuss them here.

Green technologies associated with green development are an important option for latecomer countries (Mathews 2017, Lema et al. 2020). Due to environmental pressures and the externalities generated, there are major local and national interests by latecomer countries in developing the capabilities needed in both the creation and the implementation of green technologies (Altenburg and Rodrik 2017). As discussed in Lema et al. (2020) and Dai et al. (2020), public policy windows may play a key role in terms of promotion, regulations and financing in green sectors. In fact, green technology catch-up paths are characterized by creation of demand by the government (e.g. subsidies in the form of feed-in tariffs), generation of legitimacy for new technological trajectories, and supply-side support (Binz *et al.*, 2017, Landini et al, 2020). Therefore, both new green technologies (such as electrical vehicles or concentrated solar power), as well as relatively more mature technologies (such as solar PV and wind energy) may represent opportunities for catch-up. Among new major emerging countries, China, India and Brazil are moving towards a leadership position in several green technologies (Altenburg et al, 2016, Corrocher at al, 2020, Binz et al., 2020). Firms in the latecomer economies have benefitted from successful technology transfer through the acquisition of licenses, designs, and consultancy services (Lema and Lema, 2012; Hansen et al. 2014). In particular, China's accumulation of capabilities has benefitted from capabilities in construction and logistics in the deployment of sustainable technologies (Nahm and Steinfeld, 2014).

Also the new technologies and the related emerging sectors of the beginning of the third millennium (artificial intelligence and its application to robotics, big data, cloud computing, 3D printing, internet of things and the other technologies associated to the so called fourth industrial revolution) may open up new windows of opportunities to latecomer countries. In fact these technologies will bring in new forms of disaggregation and disintegration of the production process (Schwab 2016: 62). Actually, at a closer look the new technologies and the new emerging sectors can be either a new window of opportunity or a source for further risk for a middle income trap for emerging economies, depending on each country's responses and readiness (Lee et al. 2020). In these sectors in fact emerging economies have to invest more, and more effectively, in digital literacy and skills, in innovation and in strengthening the ICT knowledge base. Of course, in certain contexts and under certain conditions, such as major access to knowledge and/or funding, latecomers may even attempt to leapfrog into newly emerging sectors, such as renewable energy or the broad spectrum of technologies associated with the fourth industrial revolution (Lee et al. 2020).

6. Summary and Concluding Remarks

This paper proposes an evolutionary view of catch-up. Economic catch-up is considered as a long-run process of closing the gap in capabilities by promoting learning and innovation in interaction with, or in the context of, the innovation systems (national, sectoral or regional). If catch-up may begin by imitating the forerunners, in the longer run successful catch-up cannot occur just by cloning existing products or technologies; rather it takes place by creating different products or technologies with respect to existing ones, or by opening completely new trajectories compared to ones of the leading countries or firms. An evolutionary view of catch-up implies heterogeneity, variety creation and different path and trajectories across technologies, products, firms and countries.

According to this perspective, catch-up is viewed as a dynamic evolutionary process which is not deterministic and cannot be planned in details, because it faces uncertainty and continuous change, is associated with a variety of exogenous events (windows of opportunity) and is the result of the idiosyncratic behavior of heterogeneous actors characterized by different understanding, views and experiences. This leads to a variety of responses and strategies (path-following, stage-skipping, and leapfrogging) by latecomer firms and countries, even in the presence of similar external technological or market conditions.

One major point that emerges from this perspective is that for successful catch-up the learning and capabilities building by catching up firms have to be supported by effective national and sectoral systems. There is a strong complementarity between learning and capabilities by domestic firms and the national and sectoral systems in which firms operate. Learning and capabilities alone will not suffice to produce a successful catch-up without effective innovation systems. However, also innovation systems which are fully developed will not work successfully if they do not generate effective learning and capability building by domestic firms.

It must be noted that in this long run evolutionary process catch-up does not stop when latecomers reach a position of leadership. This is because catch-up is evolutionary in the sense that after obtaining a position of leadership, the new leaders may in turn lose their position to other emerging firms and countries, which have undergone a rapid process of learning, capability accumulation and system building. In sum, catch-up is a continuous process of catching up, forging ahead and falling behind.

Moreover, while the literature tends to emphasize the primacy of manufacturing in catching-up, we observe that the manufacturing to service sequence is just one of the options for latecomers, given the already high entry barriers in some of manufacturing sectors. As discussed in section 5, several alternatives exist, including leapfrogging first into short-cycle services, value-deepening in resource-based sectors or combining services and manufacturing by taking advantage of emerging technologies in the era of the so-called fourth industrial revolution. The process of catching-up is not deterministic but a dynamically evolving process, always seeking niches and taking advantage of new window of opportunity associated with not only hard core innovations but also new business models.

This evolutionary view of catch-up implies an ample room for public policy, because there can be a high degree of not only market failure (as mentioned in the traditional literature) but also, more importantly, of capability and system failures. Policies that aim to correct learning and capability failures may be directed at the education and training system, the diffusion of new technology and the favoring of cooperation among domestic and foreign actors (Lee et al 2020). Policies that aim to correct failures in the working of innovation systems may address the development of a knowledge infrastructure, appropriate financial conditions or a context conducive to learning (Metcalfe, 2005; Malerba, 2009; Dodgson et al. 2011). Policies may have also to address the mismatch or lack of coordination among the various elements of the innovation system (including firms), which require trying to re-align actors and institutions in an effective way (Lundvall, 2017). However, in order to help and support dynamic evolutionary process, policies need to be flexible and change and evolve over time, in tune with the various stages of the catch-up process.

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Figure 1. Evolutionary Perspectives on Economic Catch-up