61. Technology catch-up

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CATCH-UP OR CONVERGENCE

The term "catching up" has been used to characterize the process whereby low and lower-middle income countries reach the level of higher income nations. Catching up thus refers to the ability of countries to diminish the productivity and income gap with respect to leading countries through investments in physical and human capital (Mytelka and Barclay, 2004). Since catching up has been recognized as a phenomenon that explains a tendency of national rates to converge (Abramovitz, 1986), the literature on it is also referred to as 'convergence' literature.[1]

Stylized facts reveal huge income differences, variation in productivity growth rates and a productivity gap across countries. Why have some developing countries succeeded in catching up to developed economies whereas many others have not? This is just one of the questions behind various theoretical and empirical studies addressed by notable economists.[2]

Ideas on the convergence hypothesis were first expressed in the mid-18th century. Contrary to Hume (1758), for whom economic growth convergence was a natural tendency, Tucker perceived that rival nations can not all proliferate simultaneously. Skill, good organization and a huge amount of capital were crucial to achieve market hegemony. Since these conditions were absent from poor countries (Tucker, 1755 in Clark 1903), he held that economic disparities would persist indefinitely and only industry could make a nation wealthy, with legal support from the state fundamental. For Adam Smith, convergence is not so evident, insofar as high productivity associated with the division of labor helps wealthy economies retain their leadership and advantages over poorer economies, despite their high salaries. Later contributions concur that poorer countries tend to grow faster in order to catch up with richer ones.[3] The former countries have great potential due to their economic backwardness and depending on their ability to imitate more advanced countries and reach cutting edge technology (Gerschenkron, 1962; Amable et al., 1997). If an economy's production growth rate falls as it develops and nears its steady state, then economies that start off poor grow more quickly and, therefore, converge with initially wealthier economies (Solow, 1957).

Many empirical studies essayed Solow's hypothesis of convergence across countries and time.[4] These works have given rise to two concepts of convergence: unconditional and conditional (Barro and Sala-i-Martin, 1992, 1995). Some, such as Baumol (1986), corroborate the unconditional convergence hypothesis. But according to "… broad consensus there is no evidence supporting absolute convergence in cross-country per capita incomes—that is poor countries do not seem to be unconditionally catching up to rich ones" (Johnson and Papageorgiou, 2020, 165).

Empirical findings point out that catching up is not a global phenomenon (Verspagen, 1991; Johnson and Papageorgiou, 2020). Some authors found that productivity labor gaps grow even more in the long term. Indeed, this process has not extended to many lagging nations in Latin America, Africa and Asia (Fagerberg and Srholec, 2008, 2017). Advancing from low

to middle and then higher income levels is possible only if countries reach sustainable higher growth rates in per capita income for a long term. But many of them are not able to overcome the obstacles and challenges and ultimately stay in the so-called "middle-income trap" (Lee, 2013, 2019). However, some countries defy their lag, confront leading countries and achieve a convergence and catch-up pattern (as the case of East Asian countries, Japan, Korea, Taiwan, Singapore and China). Additionally, countries near the technological frontier will have lower growth rates and thus fewer opportunities for high productivity growth (Verspagen, 1991; Acemoglu et al., 2006). Nevertheless, these countries started to join the convergence club (Baumol, 1986; Rodrick, 2013; Howitt and Mayer-Foulkes, 2005; Catellacci and Archibugui, 2008).

TECHNOLOGICAL GAP HYPOTHESIS

The technological gap approach associates technological level with innovation progress.[5] The hypothesis behind it is that labor productivity growth is greater in countries with lower initial productivity levels insofar as they can take advantage of technology that exists in advanced countries through technological assimilation processes and, as a result, in the long term, develop processes convergent with leading countries. Moreover, this hypothesis stresses that technological change spreads as a public good, benefiting other countries with lower technological levels through free accessibility to knowledge which, can substantially increase productivity and growth. Accordingly, the catch-up concept involves how countries with relatively low technological levels may benefit from the accumulated global technological knowledge available (Rogers, 2003), developing learning and absorption capabilities for exploiting technological progress and therefore attaining higher productivity. The catching-up concept specifies two essential particular but reciprocally related concepts: productive capabilities and productive capacities, which encompass structural change and productive transformation process. Productive capability involves a transformation process where countries gradually enter a complex technological knowledge environment. Over time, as catch-up takes place or makes considerable progress, upgrading the ensemble of national capabilities becomes imperative in order to engage higher complex knowledge domains and related activities. Productive capacities comprehend collective learning, a broad learning strategy that suggests economic dynamics where agents and institutions have internalized the innovation culture, including creativity and receptivity towards technological and institutional progress with steady new ideas (Fagerberg and Godinho, 2008; Nübler, 2014) The intellectual property rights policy is appropriated within an environment of innovation. Firms, institutions and even individuals assume the patent culture as commonplace, and it is part of the catch-up process.

FACTORS EXPLAINING TECHNOLOGICAL CATCH-UP

The processes of economic convergence or divergence and catch-up have been associated with differentials in technological development and human capital (Nelson and Phelps, 1966; Abramovitz, 1986; Maddison, 1987; Fagerberg and Srholec, 2017), among other factors. So, the role of technology is implicit in the classic hypothesis of economic convergence across

countries but also includes human abilities (Abramovitz and David, 1996) and social capabilities (Abramovitz, 1986).

Among the factors that contribute to technological catch-up, technology transfer (TT) was first identified centuries ago.[6] However, authors differ with respect to the strategies countries use to take advantage of TT (Fagerberg and Godinho, 2004). Veblen considers that countries might transfer technology easily through the coordination of market forces alone, without efforts to build a certain level of human skills and infrastructure. In turn, Gerschenkron finds it necessary to rely on these human and physical capabilities, including active private or government organization intervention in market scope, to ensure a successful catch-up process.

By acquiring foreign technology at frontier level, countries could engage in building and developing technological capabilities, identified as effective skills for the use, assimilation and adaptation of current technologies through technological knowledge achieved (Kim, 1997; Lall, 1992; Westphal et al., 1985).

When the initial relative technological level of countries is very low, the technological appropriating process might also be low. Therefore, effort is required of developing countries to learn and absorb technology from the rest of the world. Technological absorption capabilities are defined as the abilities of firms to recognize the value of external information from potential external partners, universities, research centers, suppliers and clients, assimilate it and be prepared to apply it for commercial goals (Cohen and Levinthal, 1990). Absorptive capability should grow relatively higher than the leader country technology rate and expertise in overcoming the technology gap (Rogers, 2003). Thus, they develop their own experiences that are accumulated in their production and innovative routines (Bittencourt and Giglio, 2013). Developing such skills involves internal, as well as external, sources. These are necessary conditions for technological catch-up.

Key to technological catch-up is the country's learning capability, which seems to be associated with an intrinsic capability but at the same time with technological distance from the leading country. By considering the enormous technological knowledge heterogeneity encompassed in heterogeneous capital goods inherent to the technology gap, the lagging or follower country will display a specific learning dynamic. On the one hand, for countries characterized by their own huge learning capacity and/or short initial gaps, catch-up is potentially possible. On the other, countries lacking or having limited learning capacity and/or in the presence of broad starting gaps will surely fail the catch-up challenges (Verspaguen, 1991; Malerba and Nelson, 2011). Literature shows evidence of how nations differ in the learning process, including both firms and government institutions; it implies technological learning in the entrepreneurial scope and government-level policy learning (Oqubay and Ohno, 2019).

In that sense, efforts reflected in policies concerning education, training, trade, investment, public and private R&D expenditure, technology transfer or investment, exchange rate and migration are central to fostering a learning strategy, providing skilled workers and building a knowledge-based environment able to deal with new routines and institutions. Top-performing learning procedures focused on firms' adoption of intensive technologies requiring a highly specialized labor force are special. But also, having communicating vessels between firms and government institutions and policies is decisive (Nübler, 2014; Kruss et al., 2015) in sectoral and national innovation systems (Nelson and Winter, 1982; Malerba, 2002; Lundvall, 1992, 1997; Fagerberg and Godinho, 2008; Malerba, and Nelson, 2011; Cimoli, 2014), where industrial policies are crucial for successful catch-up (Mazzucato, 2019).

Thus, investment in physical and human capital in underdeveloped countries must reach higher growth rates, but such countries should also undertake and increase R&D activities. Once the imitative and innovative model settles, the interrelationship established between R&D and patents, capabilities for innovation, technology transfer and growth of productivity will probably enable follower countries to join the path of technology and innovation convergence and catch-up.

The differences in quality of institutions could play an essential role in the process of technology catch-up across countries.[7] The quality of public policies and institutions is a decisive factor in economic growth (Mazzucato, 2019) and consequently can boost or hinder convergence.[8] So, countries with better institutional performance will embrace new technology faster, getting close to the frontier and reaching higher multifactorial productivity growth rates. In the presence of inefficient institutions, on the other hand, technological catch-up could be missed and rather lead to a divergence path.

Nevertheless, some institutions, such as intellectual property rights (IPR), have a contrasting role in countries with different income levels. On the one hand, IPR constitute an incentive to innovate for advanced or technological leading nations, through a novelty protection regime that assures R&D investment return over delimited time. But for lagging or technological follower countries, IPR become a kind of entry barrier, reducing technology imitation and thus slowing down technological catch-up. Otherwise, open trade favors technological spillovers provided that follower countries possess a certain level of learning capabilities and expend on R&D activities to develop technological absorption capabilities (Manca, 2010).

Besides international trade, technological diffusion and direct foreign investment (Mytelka and Barclay, 2004) affect the technology transfer rate. They are dissemination channels with a positive impact on innovation growth and labor productivity rates in technology importing countries. Under such circumstances, less advanced countries can converge and catch up to the leaders, considering some specific aspects. In an open trade framework, the imitation process has been crucial for countries such as Japan and Korea to catch up. It favors improving local technology, enhancing investment, raising the growth rate and consequently increasing intensive technology imports (Baumol, 1986; Gomulka, 1990). These types of economies may experience high growth rates because imitating technology is less costly than innovating. In particular, there are sectors where imitation is more advantageous, substantially reducing costs, such as chemistry, electronics, machinery, and pharmaceutics (Mansfield et al., 1981), lowering times for learning and adoption of external technology (Teece, 1977; Mansfield, 1985) and development of new ideas (Caballero and Jaffe, 1993).

The propensity to patent is influenced by demand and market size associated with the type of industry factors. An inverse relationship exists between intellectual property costs and propensity to patent, although there are also country differences. Another aspect that affects propensity to patent is *expected obsolescence*, which tends to be greater with the participation of foreign inventors (non-residents) in certain industries or fields of investigation (Mansfield et al., 1981; Ye and Zhang, 2019).

Technological factors, as well as investment intensity and patents, are crucial for sectorial market shares, increase technological capabilities and competitiveness, contributing to technology convergence and catch-up (Dosi et al., 2015).[9]

TECHNOLOGICAL AND SOCIAL CAPABILITIES AND THE CHALLENGES OF LEAPFROGGING IN INNOVATION SYSTEMS

Countries boast larger growth rates not only following a process of catching up but also of grasping multiple development objectives: productivity increase, generation of productive and good jobs, and rapid and sustained learning processes (Nübler, 2014; Cimoli, 2014). Thus, catching up could be considered a process of productive transformation which embraces both technological change and diversification or specialization into new economic activities and sectors, discovering niches for entry and endurance (Lee, 2013, 2019; Lall, 2000). It implies productive transformation dynamics and a process dimension that less developed countries would undertake. Catch-up envisages a technological change and diversification pattern with the speed and sustainability that less developed countries need to undertake it (Nübler, 2014).

As firms and economies develop capabilities, they can produce ever more complex goods and developing technologies (Hausmann and Hidalgo, 2011; Lee, 2019; Oqubay and Ohno, 2019). Enterprises, agents and institutions on this course shape their behavior and performing competences in the various tasks within the productive, organizational, innovation and learning and innovation challenges (Nelson and Winter; 1982; Nelson, 2008; Teece, Pisano and Shuen, 1997; Park and Ji, 2020).

Some other authors find that productivity convergence in some sectors is associated with structural changes (Chansomphou and Ichihashi, 2013; Hidalgo, 2009). Moreover, countries with new technology capability acquisition and dissemination will experience faster growth (Dahlman and Nelson, 1995; Rogers, 2003).

In the case of new sectors or new technological paradigms, poor countries are far from the technological frontier. However, their priority to acquire TT and increase scientific and technological efforts in order to learn and absorb novelties and profit from the trade in knowledge externalities in a modern institutional context could be an initial step in breaking into these sectors. East Asian countries have developed previously nonexistent high technology sectors such as information and communication technologies (ICT), biotechnology and, recently, industry 4.0 and nanotechnology (Ye and Zhang**,** 2019). In this process, industrial policies have been key to building export capacities in strategic complex sectors and accomplishing the structural transformation and technological learning required to catch up (Liu et al., 2017; Lin and Zhang, 2019; Poon and Kozul-Wright, 2019; Mazzucato, 2019).

Among countries that remain far from embarking on a catch-up route, Latin American countries lack institutional structures and agents involved in learning communities and economies with the knowledge to undertake transformations that lead to convergence processes (Peres and Primi, 2019). The reduced economic growth and social agenda lag in Latin American countries have been associated with ever lesser efforts aimed at driving technological change and innovation within the framework of articulating industrial, educational, financial, intellectual property and regulatory policies, in addition to macroeconomic stability. This goes back to the fact that countries in the region lack national innovation systems and/or suffer the effects of breakdown among the agents and institutions of the systems that should promote innovation. Creating virtuous circles that include development of learning, imitation and innovation capacities is a huge challenge for Latin America (Guzmán et al., 2016).

Countries that successfully follow a convergence and technological catch-up route contribute intriguing evidence regarding the role played by creation of sectoral and national systems and specialization in highly technological productive activities in their profitable technolog-

ical and economic catch-up processes. However, such processes have involved institutional policies (educational, intellectual property, financial, macroeconomic, political and industrial) that have joined forces in the construction and development of learning capabilities within an evolutionary process of creative response, ongoing absorption of knowledge spillovers and IPR (Schumpeter, 1947; Antonelli, 2017; Aiginger and Rodrik, 2020). The challenges faced by nations with economic and other crises involve developing new technological knowledge based on development and technology science.

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