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HOW DO HIGH, MEDIUM AND LOW TECH FIRMS INNOVATE? A SYSTEM OF INNOVATION (SI) APPROACH

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Abstract

In the past decade, the innovation literature has mainly targeted high-tech (HT) sectors due to their higher return on investment and important role in building new societies and economies. While the high-tech sector is still of a leading importance, whether medium and low tech (LMT) sectors should be equivalently considered when analyzing long term economic growth, in both leading and catching up economies, is a fundamental question. This paper is our second milestone comparing HT and LMT sectors from an innovation perspective, using a National System of Innovation (NSI) approach. The general aim of this paper is to find the main principles that govern the difference between the two industrial segments (HT and LMT) while controlling for supranational boundaries. In order to measure the effect of NSI, countries are divided into two groups: leading and catching up economies. Our results suggest that, with respect to HT, leading economies can be considered as innovators, while catching up economies are the imitators. Furthermore, HT in leading economies relies on product modularity to outsource various components probably to firms in catching up economies. Catching ups are putting greater emphasis on universities to produce knowledge. In addition, firms in catching up economies benefit from high accessibility to funds in order to grow various industrial sectors, especially LMT. The role of institutions and governments with respect to regulatory policies, intellectual property protections are of high importance for firms in catching up economies, especially in LMT. As a result of those important steps, the various agents in catching up economies have achieved sustainable growth, notably in LMT. In contrast, the same growth is observed for HT for firms in leading economies. Our results suggest that catching up countries are strategizing for this sectoral evolution, renewal and transformation process for both sectors, but with a stronger emphasis on LMT.

Keywords: *Knowledge, systems of innovation, catching up, low and medium technology, high technology*

Introduction

Recent history witnessed two major wars that shaped the world, World Wars I and II. Prior to the two wars and in the 18th century, the United Kingdom led the industrial revolution with the generation of various advancements in different industrial sectors such as manufacturing, mining, transportation, and others. The products of such technological innovations marked the birth of a new world, a world that was dominated by a radically new industrial and technological innovation setup that we still live up to. Whether innovation brings war, or war brings innovation is a complex question, which is not the scope of this paper. However, it remains unquestionable

that leading nations, from a technological innovation perspective, enjoy wealthier economies and healthier sustainable growth.

Therefore it is interesting to develop an understanding of the differences between the leading and catching up economies, and how, after World War II, the two groups of nations dealt with technological innovations. In addition to the national segmentation and due to the notion of convergence, it is imperative to understand how the same factors that shaped the supranational system of innovation also shaped, and were shaped by, the various sectors. It is important to highlight that after World War II, the US dedicated a special attention to innovation in defense, safety and health (Bruland & Mowery, 2005). This extra attention led to the development of the High Tech (HT) sector, which also attracted a great deal of investment from the various leading countries, following in the foot steps of the US. As a result, other traditional Low and Medium Tech (LMT) sectors lost their importance to a great extent.

Recent studies (Von Tunzelmann & Acha, 2005; Robertson et al., 2009; Santamaria et al., 2009) have demonstrated the increasing importance of LMT in innovation studies, a sector that has long been neglected in favor of the highly rewarding HT sector. The LMT industry, classically thought of as mature and slow, has started to shift from a cost-based strategy towards a differentiation strategy. Furthermore, while HT and LMT dominated the developing as well as the developed countries almost equivalently, some LMT activities are shifting towards newly industrialized countries (Robertson et al., 2009). The renewal and transformation of any industrial sector is therefore inevitable.

This study, among a series of a recently published work, aims to highlight the importance of LMT, compared to HT, while adding another comparative dimension: the leading versus the catching up economies. Controlling for supranational systems enables us to understand the context of innovation and whether it differs between the two groups or not. For instance, due to globalization, firms aiming to satisfy international customers needed to properly analyze the complex global taste while keeping health and safety regulation into perspective. Mendoca (2009) shows that developed countries enjoying active HT, have other sectors industrially active as well.

Therefore the main topic that concerns this paper is the relationship between leading and catching up economies, with respect to HT and LMT industries, from an innovation perspective. This is achieved by analyzing more than 500 firms distributed in the two types of economies (leading and catching up), in both the HT and LMT sectors. A system of innovation (SI) approach is used including the various agents that represent the core of national systems of innovation (NSI) and sectoral systems of innovation (SSI). Using t-tests for the comparison of means between the four groups highlighted (in Table 1) enables us uncover the differences between different systems of innovation.

Our results suggest that a renewal and transformation in the HT and LMT is taking place. This renewal process is not in isolation of the national system of innovation. While leading economies are primarily focused on HT, catching up economies are more diversified but put more focus on LMT. The paper follows with the theoretical framework, methodology, results, analysis and finally a conclusion.

HT (Leading vs. Catching up) (Group 1)	**LMT** (Leading vs. Catching up) (Group 2)
Leading (HT vs. LMT) (Group 3)	**Catching up** (HT vs. LMT) (Group 4)

Table 1 - SSI & NSI comparison map

Theoretical Framework

The theoretical framework explores two dimensions. The first dimension presents systems of innovation that include both sectoral systems of innovation (SSI), national systems of innovation (NSI), and the theoretical framework based on the two systemic approaches. The second presents the literature of catching up and leading economies from an innovation perspective.

Systems of innovation

This research follows a 'systems of innovation' (SI) approach. This systematic approach for studying innovation stems from to the necessity of incorporating innovation within its surrounding environment which constitutes the determinants of the innovation process (Edquist, 2005). This environment consists of the various important aspects that breed innovation, generally including organizational, institutional, political, social and economic factors. Consequently, when studying innovation from an SI perspective, these various factors ought to be considered, in order to properly understand the innovation phenomena. This systematic view, does not consider the mentioned entities in isolation, but in an interaction framework. For instance organizations could be other firms (such as suppliers, competitors, customers, etc.) or non-firm entities such as universities and governmental institutes (Edquist, 2005).

Systems of innovation can be national, sectoral and regional (Edquist, 1997). *First,* the National System of Innovation coined by Freeman (1987) can be defined as "the network of institutions in the public and private sectors whose activities and interactions initiate, import and diffuse new technologies" (Edquist, 2005). Following Freeman, Nelson (1993) and Lundvall (1992) published two books on NSI: Lundvall (1992) places interaction between the various agents and learning at the center of the analysis, while Nelson (1993) focuses solely on a nation's research and development systems as a catalyst of the innovation process. Both Lundvall and Nelson define NSI by determining the factors influencing innovation (Edquist, 2005). *Second,* the sectoral approach developed by Breschi and Malerba (1997) puts more emphasis on production, and utilization of technologies by the various sectors. *Third,* regional systems of innovation, first introduced by Cooke et al. (1997), concentrate on the local interactions between organizations (Edquist, 2005).

Figure 1 presents our sectoral and national systems theoretical framework. This national system bypasses geographical boundaries to include the two groups studied, i.e. the leading and catching up economies. According to Malerba (2004), sectoral innovation is affected by three main entities: knowledge and technologies, actors and networks, and institutions. First, *knowledge and technologies* represent the sectoral knowledge base, technologies and inputs, and are responsible of the sector's boundaries. This is why its box leads to dynamics and growth patterns that influence the sector's evolution and transformation. Second, *actors and networks* simply represent the various organizational entities involved in the innovation process such as firms and financial organizations, or non-organizational entities such as universities. The customers that can take various forms of organizational structures are the demand creators, and are a fundamental part of the sectoral system of innovation. Using a knowledge-based view of the innovation process, the different entities are all interconnected by arrows. Third, *institutions* are basically the bodies responsible of norms and routines, such as public funding institutions, regulation and standards institutes. Such institutions have both sectoral and national roles.

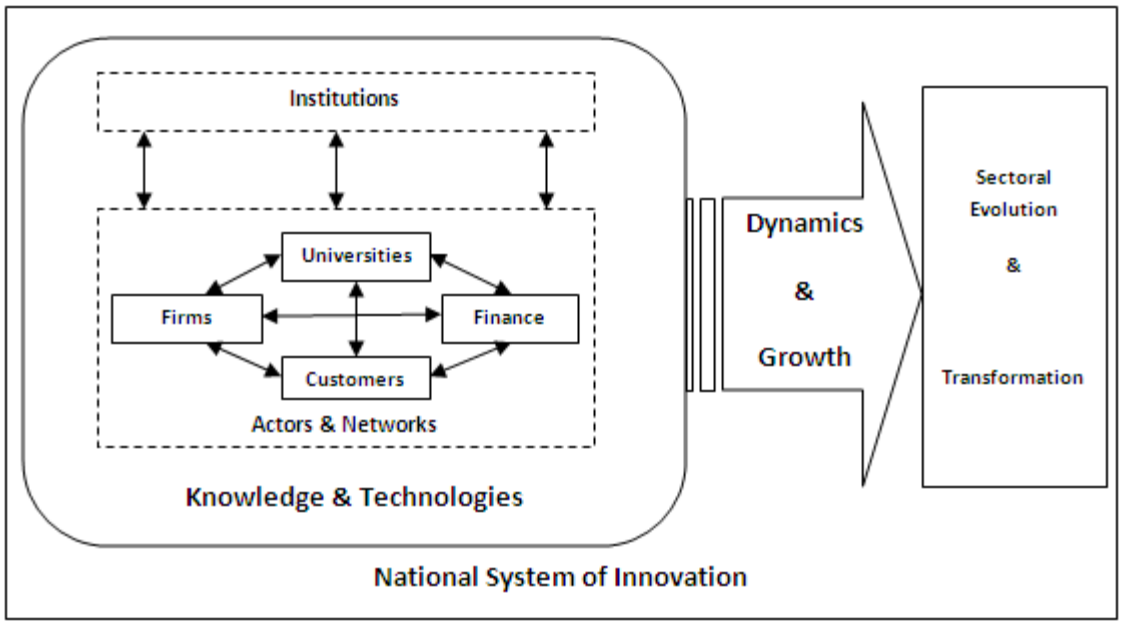


Figure 1 - SSI and SSI Theoretical Framework

The representation of our theoretical framework not only follows Malerba's (2004) view of an SSI, it also takes into consideration Freeman's (1987) structure representing the network of institutions, and their interactions. These interactions will generate the learning process, a phenomena that is heavily supported by Lundvall (1992). Due to the dynamic nature of the interactions and of learning, sectors go through various dynamic and growth patterns that result into the evolution of the sector and its transformation. Each block in Figure 1 are represented in the questionnaire used for our research, and described below.

In order to process to our analysis, two main questions remain to be answered:

1. What is the main difference between LMT and HT according to each of the variables of our theoretical framework?
2. What is the main difference between leading and catching up economies according to each of the variables of our theoretical framework?

According to Figure 1, the LMT and HT are addressed from the point of view of sectoral/national systems of innovation. Table 2 illustrates our general understanding of the importance of each element based on the literature, classified into low, high and moderate. Knowledge and technologies are investigated from five angles. The first and second are addressing whether firms gain knowledge by accumulation from inside the firm (KTIn) or rather by interactions with other firms (KTOut). Furthermore, systems integration (KTSys) is considered to be a way of exchanging knowledge about the various systems standards, especially between the various suppliers. The last angle considers whether knowledge is actually the production of a stable (KTStab) or more dynamic technological base. Recent literature suggest that LMT firms depend more heavily on their suppliers, and hence are more oriented towards open innovation, whilst HT firms are more oriented towards the linear model of innovation, depending mainly on their internal R&D production, while using collaboration and open innovation to develop technologies that cannot be provided from within the firm. Both sectors integrate systems; however, due to the modularity that is currently very widely used in HT, we can generally claim that the HT would be more dependent on systems integration than LMT. HT is viewed to be more of a turbulent sector that enjoys dynamic technological change, compared to LMT that is considered to be more stable, mature and less dynamic. Furthermore, HT is the main producer of General Purpose Technologies (GPT), while the LMT is the main user of GPT (Robertson et al., 2009, Freddi, 2009) (KTGPT).

The element relating to actors and networks consists of universities, firms, customers (demand) and finance. HT depends heavily on scientific knowledge produced by universities (ANUniv), compared to LMT that is more dependent on practical solutions that are widely shared between customers and suppliers. Universities are thus marked with ‘low’ with respect to LMT and ‘high’ with respect to HT.

Firms’ strategy can include the following: supplier dependency (ANSupp), modularity (ANMod), standards war (ANStd), cost/differentiation orientation (ANCost), or process/product innovation (ANInnov). While both sectors depend on suppliers, according to Pavitt’s (1984) taxonomy, LMT (specially the low techs) is more of a supplier-dominated sector. For this reason, LMT is assigned a ‘high’ importance, while HT is assigned a ‘moderate’ importance for supplier dependency. While modularity is commonly used across the various sectors, comparatively, HT products are more modular than LMT ones. Due to this modularity, standards have a higher effect on HT than its counterpart. In addition, LMT, as a mature sector, is considered to be cost oriented, while HT is rather oriented towards technological differentiation. Furthermore, demand is generally more complex in HT than in LMT. With respect to financing, it is expected that HT is receiving better financing, than classic sectors.

SSI & NSI Basic Components	Elements		Variable	LMT	HT
Knowledge and Technologies	Accumulation Inside Firms		KTIn	Low	High
	Firms Interactions		KTOut	High	Low
	Systems Integration		KTSys	Moderate	High
	Technological Stability		KTStab	High	Low
	General Purpose Technologies (GPT)		KTGPT	Low (Using)	High (Producing)
Actors and Networks	Universities		ANUniv	Low	High
	Firms Strategy	Supplier Dependency	ANSupp	High	Moderate
		Modularity	ANMod	Low	High
		War of Standards	ANStd	Low	High
		Cost Orientation	ANCost	High	Moderate
		Process\Product Innovation	ANInnov	Process	Product
	Demand	Customers & Complexity of Need	ANNeed	Low	High
	Finance		ANFin	Low	High
Institutions	Regulatory		IReg	Moderate	High
	Intellectual property		IIP	Low	High
	Government Funding & Support		IGov	Low	High
Dynamics and Growth	Sectoral Growth		DGGrowth	Low	High
	Dynamics	Pace of change	DGPace	Low	High
		Firm's entry	DGEntry	Low	High
		Incumbent firms challenge	DGIchal	Moderate	High
		Rival challenge	DGRchal	Low	High
		Battles of Cost	DGCost	High	Moderate
Sectoral Evolution and Transformation	Technological Frontier Advancement		ETTech	Low	High
	Sectoral Transformation		ETTrans	Moderate	High
	Sectoral Redefinition		ETRedef	Moderate	High
	Unpredictable sectoral Development		ETDev	Low	High

Table 2 - HT and LMT from an SSI \ NSI view

Regarding the role of institutions, regulations (IReg) are an important aspect when it comes to the diffusion of HT technologies. This factor is indeed crucial for LMT especially with the increasing role of globalization, and the rise of various health and security international policies. As HT is to be considered a principal component of the knowledge economy, knowledge in that sector is a product that should be protected. Hence, for HT, the role of intellectual property protection (IIP) is generally more central than for LMT. Governmental funding and support (IGov) is still generally directed towards HT due to its important role in our current economies. In contrast to HT, LMT does not enjoy much of that support due to its slow growth.

Dynamics and growth are represented by various factors that include growth (DGGrowth), pace of change (DGPace), firm entry (DGEntry), incumbent firms challenge (DGIchal), rival challenge (DGRchal) and cost battles (DGCost). As HT is more dynamic and provides more growth than LMT, all factors are marked with 'high' in favor of HT, with the exception of two factors. Incumbent firms challenges is not low in LMT, where in fact incumbent firms enjoy early mover advantages that are hard to penetrate by rival new entrants. The other factor relates to cost battles, where generally mature sectors are more inclined to be more competitive on cost

compared to younger sectors that use technological differentiation as a core competitive advantage. Finally, with respect to sectoral evolution and transformation, it is measured by four main factors: technological frontier advancement (ETTech), sectoral transformation (ETTrans), sectoral redefinition (ETRedef) and unpredictable sectoral development (ETDev). Since HT is a more dynamic and growing sector we can infer that its sectoral evolution and transformation will be higher than LMT across all factors. However, since recent literature supported the propensity of LMT transformation and redefinition, we can generally claim that the two factors could be assigned a 'moderate' mark.

Catching up and leading economies

"'Catch-up' relates to the ability of a country to narrow the gap in productivity and income vis-à-vis a leader country" Fagerberg and Godinho (2005, p.514). In the nineteenth century, the United Kingdom was classified as the leader, while the United States and Germany were trying to catch-up. This process of narrowing the gap between the leader and the follower was not the result of pure imitation. Indeed it was done by bringing new ways of organizing production and distribution, in other words through innovation (Freeman and Soete 1997; Freeman and Louca 2001). Van Schaik and Van de Klundert (2010) have examined this 'innovation versus imitation' dichotomy for 21 OECD economies from 1960 to 2005. They found that two sub-periods of technological change are identifiable. The first is based on imitation; the second is predominantly based on innovation.

In 2007, the society of manufacturing engineering (Sme, 2007) highlighted that the US is still leading the entrepreneurial performance but other nations are catching up. It is estimated that by 2020, this catching up process will be at its peak. This will be due to multiple reasons the most important of which is that middle class consumer demand will emerge from non-industrialized countries. In addition, China is becoming the most attractive destination for off-shore R&D activities. When analyzing the compact disc player in China, Xie and Zedtwitz (2010) found that innovation is mainly pulled by local markets rather than by technology push.

According to Fagerberg and Godinho (2005), the catching up literature includes three important views: the first is that of Thorstein Veblen and Alexander Gerchenkron who analyze the catching up of Germany towards the UK and the role of institutions to realize the process; the second is the literature of Asian (including Taiwan, South Korea and others) catching up towards the Japanese way; finally the third relates to the role of technology and innovation resulting in long run economic growth.

European history is central to the understanding of the catching up phenomena. Veblen (1915) was the first to realize that "recent technological changes altered the conditions for industrialization in latecomer economies" (Fagerberg and Godinho, 2005, p.516). At the beginning of the industrial revolution, knowledge was tacitly embedded in skilled workers, and hence knowledge transfer was the result of these workers' mobility. However, with the recent advances in the codification of knowledge, latecomers can actually take the full benefit from the technology without contributing any cost to its development. Veblen predicted this catching up phenomenon for other countries such as France, Russia, Italy and Japan.

Alexander Gerchenkron (1962) did not share the same opinion as Veblen (1915). Gerchenkron argued that Veblen's view of the catching up phenomenon was based on the case of UK and Germany. This form of industrialization that Britain witnessed at that time was actually small scale and fitted Veblen's view, which did not include the important role of institutions. Therefore, according to Gerchenkron, to succeed, catching ups should develop separate institutional instruments that are uniquely distinguishable from that of leading economies. Consequently, Gerchenkron attributed the successful catch-up to the role of banks, governments or private organizations in the industrialization process (Fagerberg and Godinho, 2005).

More literature explaining the catching up phenomenon of the Asian countries post WWII followed either Veblen or Gerchenkron views. However, most researchers (Shin,1996; Wade, 1990) would agree that Asian catch-up strategies were much aligned to Gerchenkron's views. Gerchenkron's view on the role of banks together with governmental support to promote catching up is evident in post WWII Japan (Fagerberg and Godinho, 2005). The role of banks and governmental support grew, compared to the private investors and family ownership that prevailed before the war. With time, the role of the state decreased, and the Japanese banking system was solid enough to sustain the industrial catching up. Furthermore, the Japanese case highlighted the role of process innovation in the catching up process. As such, the Japanese case was a leading example for other catching up economies in Asia such as South Korea and Taiwan (Fagerberg and Godinho, 2005).

On the macro view, according to Fagerberg and Godinho (2005, p. 524), Abramovitz (1986 & 1994) explains the discrepancies between countries performances by "congruence and social capability". The first concept is basically how national systems are different from, or similar to, each other in terms of various economic characteristics such as factor supply and market size. The second concept includes various factors such as the education level and the levels of investment in R&D as well as the role of the financial system to mobilize resources (Fagerberg and Godinho, 2005).

Data and Methodology

Data

Data is the result of a survey questionnaire[1] sent in the scope of MINE project to more than 900 firms. Firms with substantial missing data for our analysis were eliminated and only 545 firms were considered in our analysis. The study uses cross-sectional data that should provide excellent insights into a wide range of descriptive issues (Chandler, 1962). The answers are represented by a Likert scale from 1 to 7, where 'one' denotes the respondent disagreement of the statement and at the other end, 'seven' implies a 'totally agree' response. The study is thus based on firm level data. All firms are sorted according to their primary activity, and are also confirmed by their North American Industry Classification System (NAICS). In our sample, leading economies are

[1] We are thankful to Prof. Roger Miller for providing us with the survey questionnaire, and the data in the scope of project MINE used in this study. Only selected variables from the questionnaire were selected and re-adapted to our problematic and the theoretical framework accordingly.

represented by Canada, France, the UK and the USA. Catching up economies include China, Taiwan, South Korea, and Peru. These 7 economies shared 73% of the critical mass of their overall sample in their own group.

Methodology

This paper tests for the equality of means between HT and LMT, across industrialized and newly industrialized economies. Firms sample size representing HT leading countries (Group 1), HT catching up economies (Group 2), LMT leading countries (Group 3), and LMT catching up economies (Group 4) are 111, 88, 195, 151 firms respectively. The t-test for equality of means is carried out with groups 1 vs. 2, 3 vs. 4, 1 vs. 3 and finally 2 vs. 4.

In order to use the t-test for different sample sizes, data is tested for normality for the various sample sizes. This first verification is carried out by checking the kurtosis and skewness of the data. The values of kurtosis and skewness are found to be around '0' and are in the interval [-1, +1]. The data is thus normally distributed. Levene's test is carried out to verify the equality of variances, between the various samples. In the Levene test, if $p \leq 0.05$ then the t-test for unequal variances and unequal sample size is used. If $p > 0.05$ then the t-test for equal variances and unequal sample size is used. Each table in the next section presents the results of the t-tests for equality of the means between the various groups from 1 to 4 (in Table 3). The t-test results follow a two-tailed representation. Therefore, the result of the two-tailed representations is divided by 2 to transform the two-tailed scale into a one-tailed scale. In results tables, non-significant p values are labeled (NS) and are shadowed.

Results

Knowledge and Technologies

Accumulation of knowledge inside firms across the four groups is comparatively non significant (KTIn). However, with all averages above 5 on the scale, it shows that internal R&D development is crucial to firms' survival, regardless of its economical or sectoral boundaries. This support's other researchers' findings, such as Tsai and Wang (2009), and shows that even firms with a higher dependability on external R&D, perform better when improving their internal R&D absorptive capacity. Results show that knowledge generation through interaction (KTOut) in LMT is the most significant across all groups for the catching economies. However these interactions are significant in leading economies with respect to HT. When comparing groups 1 and 2, and groups 2 and 4, results are non significant. The most significant result, when it comes to systems integration (KTSys) and the knowledge generated during such a process, is HT in leading economies, when compared to LMT in the same economies. HT in leading economies views systems integration as a more centric process than the same sector in catching up economies. However, if the two economies are compared, LMT in catching up economies relies more on system integration to generate knowledge.

LMT in both economies rely more on a stable technological base (KTStab). This is in contrast to HT that enjoys a more dynamic technological environment. Interestingly, catching up economies, perceive knowledge generation to be more dependent on a stable technological base,

compared to leading economies. This could hint that while the leaders are the innovators in both sectors, the catching ups are the imitators. General Purpose Technologies (GPT) is the product of HT. However, if comparing catching up and leaders with respect to GPT (KGpt), results are non-significant, suggesting a kind of closeness in the way knowledge is used to produce GPT in both economies.

Actors and Networks

When comparing HT or LMT in catching up economies, non-significant results occupy the majority of the innovation context (see 2 vs. 4 in Table 3). This probably suggests that the HT and LMT sectors are similarly viewed by catching up countries. In both types of economies, HT is more aligned with universities (ANUniv1 & ANUniv2) to produce knowledge than LMT. However, when the two economies are compared, controlling for one sector, catching up economies are seen to be putting extra focus on knowledge produced by universities. This result supports the findings of Mazzoleni (2008) who discovered that for a successful catching up process, academic institutions have to contribute to the development of firm level capabilities. This kind of close interaction between the academic and industrial sectors, together with the government, has been emphasized by Tu and Yang (2008) to promote Taiwan's Science and Technology (S&T) contribution to the catching up process.

Suppliers play a key role in HT located in leading countries, compared to LMT in their own economies (the leading one) (ANSupp). This suggests that while the core products architectures are still produced in leading economies, the dependency on external suppliers probably increased particularly with the general trend of product modularity. This is supported by Xie and Zedtwitz (2010) who found that on the supply side, suppliers from leading economies play a key role for firms in China to produce 'world-first' products and innovations. For instance, in both types of economies, HT still is more dependent on product modularity (ANMod). However, leading economies are probably incorporating modularity in their firm's innovation strategies better than catching up economies. A good explanation is that firms in leading economies produce modular products, and then outsource components to catching up economies. This downstream integration capability is essential for catching up economies to succeed (Xie & Zedtwitz, 2010). Furthermore, this intra-industry trade has increased products quality, and enhanced the catching up process for Eastern European countries and their EU partner (Cavallaro and Mulino, 2008).

This could explain why HT in leading economies became more supplier-dependent. For that reason our results show that the standards war (ANStd) is better mastered by leading economies especially in the HT sector.

Cost is represented by two variables, one is related to the constraint facing firms (ANCost), the second is related to reducing cost by increasing the scale of operations (ANCostScl). Generally more than 50 percent of the results are NS for all comparison. For instance, with respect to cost as a constraint (ANCost), the only significant comparison is that comparing LMT and HT in leading economies (1vs3) in favor of the LMT. This demonstrates that most of the firms in the two economies generally perceive cost as a major determinant for their strategic directive, with a higher emphasis on LMT in leading economies. Furthermore, scale contributing to cost reduction (ANCostScl) is the most significant when comparing LMT in both economies, in favor of

catching ups. This suggests that catching ups are probably using higher scale production to minimize cost in LMT, probably due to their relatively lower labor costs and scale intensive operations. This mix between integration capabilities, with competitive pricing has been stressed by (Xie & Zedtwitz, 2010).

Investigating the role of product/process innovation at the firm level (ANInnov), catching up economies rely more on process innovation, especially in LMT. This is apparent in the comparison between 3 vs. 4 and 2 vs. 4, and is consistent with our general understanding that reinforces the high value of LMT to the catching up process. In other words, since LMT is generally considered to be process innovation driven, firms in countries encouraging LMT should be also highly focused on process innovation. That finding is consistent with those of Merikull (2010), studying eastern European countries. Based on the Estonian community innovation survey (CIS), he found that innovation affects positively employment growth in the Estonian LMT sector, where the stronger effect was caused by process innovation. This highlights the importance of process innovation to the catching up process.

HT is generally facing a more complex demand (ANComp) compared to LMT. The complexity of demand in leading economies surpasses that of the catching up economies. This probably explains that leading economies, while focusing on local markets try to penetrate foreign markets. This is evident from the behavior of American multinational enterprises scattered all over the globe that aim to satisfy demand from various global users. The rise of product modularity certainly enables firms to better customize their products to fit a variety of customer needs and demands. In addition to complexity, experienced customers (ANComp) about product's operation hold the highest significance for the LMT sector when the two economies are compared. This demonstrates the importance of clients for firms in LMT especially in catching up economies that seems to highly value the role of interaction with clients to better customize demand.

What is even more interesting is that innovative start-ups, in catching up economies, enjoy a higher level of accessibility of funds to grow their businesses (ANFin). This result is consistent in both the HT and LMT (highly significant). This result supports the findings of Hsieh and Lofgren (2009), highlighting the importance of funds accessibility for the catching up process in Korea, Singapore and Taiwan. Fund could take the form of public investments and grants or foreign direct investment (FDI).

Institutions

Catching up economies are more concerned with regulatory approvals (IReg) in the LMT sector. This suggests that catching up economies that are very dependent on exports take regulations seriously before their product commercialization phase as a part of their institutional setup. Furthermore, in both sectors, catching up countries seem to be taking important measures to avoid any imitation (IRegIm) of their own innovations. This is even more apparent from the fact that intellectual property protection (IIP) is very significantly in favor of catching ups versus leading economies, and in the two sectors. This effectiveness in utilizing the intellectual property system indicates the importance of efficiently capturing value from innovations for firms in catching up economies.

Governmental support (IGov) is important in the high tech industry in both economies. While this support is clear in the case of leading economies, it is important to further analyze it from the catching up economies angle. Studying the biopharmaceutical sector in South Korea, Singapore and Taiwan, Hsieh and Lofrgen (2009) attribute the catching up process in that sector to two important government related factors: First, public investment in R&D; Second, the role of catching up governments to promote high tech industries by promoting public investment, establishing R&D tax credits. According to the authors this governmental role is indispensable for the catching up process especially in the high tech industries. It is also important to mention that catching up governments are mixing the sources of funds between Foreign direct investment (FDI) and local governmental funds. This mix in the sources of funds has been proven to be a success for the catching up process (Bellone, 2008).

Leading and catching up economies are nevertheless giving a considerable attention to the HT sector. However more focus seems to be given to LMT in catching economies if compared to the LMT of leading ones.

Dynamics and Growth

Catching up economies, with respect to both sectors, are witnessing a remarkable growth compared to that of leading economies (DGGrowth). This growth reaches the highest significance for LMT, but HT is still overshadowing LMT in leading economies. The dynamics of this growth are further supported by the several variables representing the pace of change (DGPace), firm entry (DGEntry) and rival challenges (DGRChal), as well as cost battles (DGCost). For instance, the pace of technological change (DGPace), induced by entry (DGEntry) in catching up economies is very clear and with a very high significance in the LMT sector. This result demonstrates that catching up economies were already following the latest recommendations of the OECD economic survey of 2010. The recommendation of OECD (2010) aims to reduce the cartels effect in order to strengthen competition and enhance the catching up process. When comparing HT and LMT in catching up economies, we find that the HT industry is characterized with a higher entry rate. This hints towards the flexibility of HT firms in catching up economies: a phenomenon that supports the findings of Li and Kozhikode (2008) when analyzing the Chinese mobile phone industry.

This rise in the role of entry (DGEntry) is opposed by a somehow relaxed role of incumbent firms (DGIChal) that are only able to control competition in their own economy. Catching up economies are pushing the HT renewal and transformation process by maintaining a cost competitive (DGCost) advantage, as a core strategy for their firms.

SSI & NSI Basic components	Elements		Variables	Group 1 HL	Group 2 HC	Group 3 LML	Group 4 LMC	1 vs. 2 P/2 [1-2]	3 vs. 4 P/2 [3-4]	1 vs. 3 P/2 [1-3]	2 vs. 4 P/2 [2-4]
Knowledge & Technologies	Accumulation Inside Firms		KTIn	5.48	5.38	5.32	5.26	0.2735 NS	0.3360 NS	0.1420 NS	0.2605 NS
	Firms Interactions		KTOut	4.55	4.76	4.05	4.59	0.1445 NS	0.0005 ****	0.0030 ***	0.1730 NS
	Systems Integration		KTSys	5.63	5.39	4.56	5.00	0.0995 **	0.0035 ***	0.0000 ****	0.0150 **
	Technological Stability		KTStab1	4.86	4.80	4.38	4.49	0.3800 NS	0.2505 NS	0.0035 ***	0.0570 **
			KTStab2	3.99	4.58	4.51	5.03	0.0035 ***	0.0005 ****	0.0045 ***	0.0065 ***
	General Purpose Technologies (GPT) Production		KGpt	5.12	5.21	4.60	4.89	0.3510 NS	0.0445 **	0.0055 ***	0.0510 *
Actors and Networks	Universities		ANUniv1	4.80	5.22	4.05	4.66	0.0210 ***	0.0000 ****	0.0000 ****	0.0015 ***
			ANUniv2	4.52	4.93	3.51	4.74	0.0295 ***	0.0000 ****	0.0000 ****	0.1620 NS
	Firms Strategy	Supplier Dependency	ANSupp	5.83	5.34	5.22	5.23	0.0035 ***	0.4710 NS	0.0000 ****	0.2765 NS
		Modularity	ANMod	6.25	5.41	5.51	5.20	0.0000 ****	0.0340 **	0.0000 ****	0.1655 NS
		War of Standards	ANStd	5.99	4.76	4.93	4.82	0.0000 ****	0.2630 NS	0.0000 ****	0.3845 NS
		Cost Orientation	ANCostScl	4.89	5.26	4.79	5.48	0.0345 **	0.0000 ****	0.2955 NS	0.1210 NS
			ANCost	4.75	4.89	5.27	5.10	0.2695 NS	0.1360 NS	0.0025 ***	0.1350 NS
		Process\Product Innovation	ANInnov	4.22	4.20	4.33	4.71	0.4555 NS	0.0100 **	0.2840 NS	0.0040 **
	Demand	Customers & Complexity of Need	ANExp	5.06	5.34	4.65	5.40	0.0850 **	0.0000 ****	0.0130 **	0.3505 NS
			ANComp	5.92	5.53	5.26	5.06	0.0150 ***	0.1175 NS	0.0000 ****	0.0040 ***
	Finance		ANFin	3.36	3.67	2.91	3.48	0.0820 *	0.0000 ****	0.0110 **	0.1670 NS
Institutions	Regulatory		IReg	4.47	4.58	4.15	4.77	0.3465 NS	0.0025 ***	0.0970 *	0.2250 NS
			IRegIm	3.48	4.32	3.34	4.34	0.0005 ****	0.0000 ****	0.2520 NS	0.4660 NS
	Intellectual property		IIP	4.43	5.28	3.77	4.84	0.0000 ****	0.0000 ****	0.0005 ****	0.0115 **
	Government Funding & Support		IGov	3.86	3.71	3.06	3.30	0.2490 NS	0.0875 *	0.0000 ****	0.0345 **
Dynamics and Growth	Growth		DGGrowth	4.05	4.59	3.08	4.45	0.0070 ***	0.0000 ****	0.0000 ****	0.2390 NS
			DGNiche	4.79	4.58	3.91	4.46	0.1695 NS	0.0005 ****	0.0000 ****	0.2675 NS
	Dynamics	Pace of change	DGPace	4.82	5.26	3.36	4.34	0.0235 **	0.0000 ****	0.0000 ****	0.0000 ****
		Firm's entry	DGEntry	4.19	4.60	3.05	3.91	0.0390 **	0.0000 ****	0.0000 ****	0.0005 ****
		Incumbent firms challenge	DGIchal	5.27	5.18	4.87	4.93	0.3110 NS	0.3565 NS	0.0050 ***	0.0995 *
		Rival challenge	DGRchal	4.58	5.00	4.24	4.97	0.0120 **	0.0000 ****	0.0170 **	0.4450 NS
		Battles of Cost	DGCost	4.33	4.93	4.52	4.67	0.0040 ***	0.2065 NS	0.1780 NS	0.1095 NS
Sectoral Evolution and Transformation	Technological Frontier Advancement		ETTech	4.97	5.24	3.33	4.35	0.0960 *	0.0000 ****	0.0000 ****	0.0000 ****
	Sectoral Transformations		ETTrans	4.76	4.95	4.49	4.87	0.1575 NS	0.0100 **	0.0745 *	0.3145 NS
	Sectoral Redefinitions		ETRedef	4.95	4.83	4.10	4.28	0.2890 NS	0.1500 NS	0.0000 ****	0.0030 ***
	Unpredictable sectoral Development		ETDev	4.08	4.84	3.63	4.45	0.0000 ****	0.0000 ****	0.0095 ***	0.0200 **

Notes: ****, ***, **, * represent significance at the 0,1%, 1%, 5% and 10% levels respectively.
Group 1 = HT Leading countries (N=111)
Group 2 = HT Catching up countries (N=88)
Group 3 = LMT Leading countries (N=195)
Group 4 = LMT Catching up countries (N =151)

Table 3 - Mean comparison analysis between the 4 groups

Sectoral Evolution and Transformation

Finally, the fifth set of rows of Table 3 addresses the sectoral evolution and transformation. For HT, compared to LMT, in both catching up and leading economies, we observe a higher advancement in its technological frontier (ETTech), sectoral transformation (ETTrans) and redefinitions (ETRedef). Furthermore, HT is perceived to be dominated by unpredictable sectoral development (ETDev). However, if we control for sector, catching up economies seem to be more strategizing for this sectoral evolution and transformation process. This suggests that catching up economies are a prime player in the renewal and transformation of the both sectors, with a stronger emphasis on the LMT.

Analysis and Discussion

Knowledge and Technologies

Internal R&D development is crucial to firms' survival, regardless its economical or sectoral boundaries. For catching ups, this result is in line with Fan's (2006) (Wei et al., 2005) recommendation in regards to the Chinese Telecommunication Equipment Industry (TEI). The author asserts that for a successful catch-up, in the TEI should focus on in house R&D development together with their focus on external alliances.

Also this result supports the findings of Fagerberg and Godinho (2005) who stated that catching ups such as South Korea and Taiwan invest more than 1.5% of their GDP in R&D. This demonstrates the race with leading countries such as the US, France and the UK.

Knowledge generation through interaction in LMT is the most significant factor in favor of the catching economies. In general, previous studies showed that this kind of interaction is central to successful LMT, due to its cost efficiency, and the high quality of knowledge produced due to interactions between the various actors of the sectoral system, such as suppliers and clients. These interactions however are significant only in leading economies with respect to HT.

Result 1: Aside from internal R&D development, knowledge generation through firm's interactions is central to the strategic innovation context of LMT in the catching up economies.

In terms of knowledge generation through systems integration, on the one hand, HT in leading economies views systems integration as a more central process than the same sector in catching up economies. On the other hand, LMT in catching up economies relies more on system integration to generate knowledge

Result 2: Leading economies are more efficiently using systems integration in the HT sector, while catching up economies are utilizing system integration in the LMT sector.

LMT in both economies rely more on a stable technological base. This is in contrast to HT that enjoys a more dynamic technological environment. Interestingly, catching up economies, perceive knowledge generation to be more dependent on a stable technological base, compared to leading ones. This suggests that while the leaders are the innovators in both sectors, the catching ups are the imitators. General Purpose Technologies (GPT) is always the product of HT.

However, if comparing catching ups and leaders with respect to GPT, results are non-significant, suggesting a kind of closeness in the way knowledge is used to produce GPT in both economies.

Result 3: In both economies, HT relies on less stable technological base, while LMT utilizes a more stable one. However, catching up economies are generally using a more stable technological base than leading economies.

Result 4: The leaders are innovators, while catching ups are imitators.

This imitative strategy has been demonstrated by Tony Yu (2005) in the case of Hong Kong manufacturing firms. He argues that three imitative strategies manufacturing enterprises have followed in Hong Kong: 'reverse value chain' strategy, 'reverse product life cycle' strategy, and process capability specialist. This imitative image is also highlighted by Yu (2007) in his analysis of the Chinese new generation mobile system. Furthermore, this imitative role that emerging economies play is studied by Li & Kozhikode (2008), particularly its implications on global R&D management. They find that while local firms generally have substantial opportunity to benefit from the knowledge spillovers from multinationals, they often lack their own firm's innovative capabilities to shift from a process oriented innovation to a product one, similarly from imitation to innovation. However, according to Yu (2007) and Dobson & Safarian (2008), this imitative Chinese image is starting to change notably in the high tech sector. This change is currently led by encouraging inter-firm collaboration using the various institutional support strategies.

Actors and Networks

Results suggest that in catching up economies, both sectors are similar; none is gaining extra attention over the other. Moreover, catching up economies are putting a higher emphasis on knowledge produced from universities to benefit both sectors. This supports the comments of Fagerberg and Godinho (2005) indicating that whilst leading economies hold a higher percentage of university enrolment, catching ups are not far from reaching the same level.

Result 5: While catching up economies assign a diversified attention to both the LMT and HT, leading economies are focused on HT. Additionally, realizing their importance, catching ups economies are putting a greater emphasis on universities to produce knowledge.

It is important however to highlight that some catching up economies such as Mexico, have been found to depend less on direct collaboration with universities, and more on university industry collaboration as a source of technological knowledge (Norma, 2005)

Suppliers play a key role in HT located in leading economies, compared to LMT in their own economy (the leading one). This suggests that while the core product architectures are still produced in leading economies, the dependency on external suppliers probably increased especially with the general trend of product modularity. However, it is essential to mention that recent research has found that the Chinese automobile industry is recently shifting from the integral architecture to a quasi-open modular architecture (Wang, 2008). Following that strategy firms buy licenses or copies of generic parts and integrates the various components depending on the end product.

Result 6: Firms in leading economies produce modular products, and then outsource components to catching up economies.

Result 7: Catching up economies rely more on process innovation, especially in LMT that seems to be a core sector.

The complexity of demand in leading economies surpasses that of the catching up economies. This probably explains that leading economies, while focusing on local markets definitely try to penetrate foreign markets.

Result 8: Leading economies firms face an even more complex demand that is satisfied by increasing products modularity.

What is even more interesting is that innovative start-ups, in catching up economies, enjoy a higher level of accessibility of funds to grow their business. This result is consistent in both the HT and LMT. However, the LMT holds a very high significance. This shows a focus on that sector in catching up economies. This supports the Gerschenkronian view that successful catching ups depended more on their internal ability to enhance their institutional role to invest properly in education, innovation and R&D (Fagerberg & Godinho, 2005).

Result 9: The economic system of catching up economies is perceived to better facilitate accessibility of funds to grow the various industrial sectors with a high significant result for LMT.

Institutions

The important role of institutions, supporting Gerschenkronian's view, is clear in our analysis. Catching ups do not only focus on education, in fact the regulatory framework in which catching ups institutions played a key role is evident. This importance is obvious in the case of HT in leading economies. More importantly, this role is paralleled by a similar role in catching ups with respect to LMT. One the one hand, leading economies protect their HT investments by developing the appropriate regulatory policies. On the other hand, catching ups are reinforcing the role of institutions especially in the case of LMT, as a mean to catch up. This result is logical, if the economic and technological perspectives of LMT are investigated. For instance, LMT firms in catching ups, that generally are expert with export, should give key attention to regulatory approvals through their institutions in order to protect their investments. In the same vein, since catching ups cannot afford much knowledge dissipation, intellectual property protection is mandatory to properly utilize innovations and protect their R&D investments. This institutional setup is supported by governments especially in the case of LMT in catching ups.

Result 10: Focused on LMT and export, catching up institutions play a key role to expand their global market share by seriously adhering to regulatory policies before the commercialization phase.

Result 11: In catching up economies, intellectual property protection institutions play a key role of efficiently capture value from innovations, and protect own production to avoid imitation.

Result 12: Governments for both economies are giving extra attention to HT. However; governments in catching up economies are giving extra focus to LMT.

Dynamics and Growth

The result of the above factors resulted into dynamics and growth of the LMT sector especially in catching ups. Leading economies are seen to focus solely on HT, with probably a diminishing growth. On the one hand, Catching ups perceive growth in both sectors with a clear lead in LMT. On the other hand, leading economies seem not to be giving much attention to LMT due to their HT focused strategy. While it is unmistakable that HT is the main engine for growth, this statement could be losing its absoluteness with time. One explanation is that HT has perhaps climbed its S shaped curve of technological innovation, and getting to be more of a stable and less turbulent sector. In contrast, LMT, considered the user of the HT products, now has a variety of technologies to deploy to enhance their process innovation, thus contributing to further differentiate their products portfolio. This suggests the renewal and transformation of such old, and slow growth perceived sector. Not only does technological differentiation, offered by the HT technologies support LMT firms, in fact this is coupled with a cost based strategy.

Result 13: In terms of growth, firms in catching up economies perceive more growth in both sectors with a higher significance for LMT. Whereas their leading counterparts are more focused on HT that takes the lion's share of attention.

Result 14: The pace of technological change in catching up economies in the LMT sector is clear. In addition, firms in the catching up economies are driving a cost based strategy in the HT sector pushing for a renewal and transformation process.

Sectoral Evolution and Transformation

As a result of the above dynamics and growth elements, the LMT in both economies is witnessing advancement in its technological frontier. And hence, this sectoral transformation and redefinition is evident. However, this renewal and transformation places strong emphasis on LMT in catching ups that seems to have managed to attract that sector to its own national boundaries, and finally lead this transformation and renewal process.

Result 15: LMT, in both catching up and leading economie,s is witnessing a higher advancement in its technological frontier, sectoral transformation and redefinitions.

Result 16: Catching up economies are strategizing for this sectoral renewal and transformation process with a stronger emphasis on the LMT.

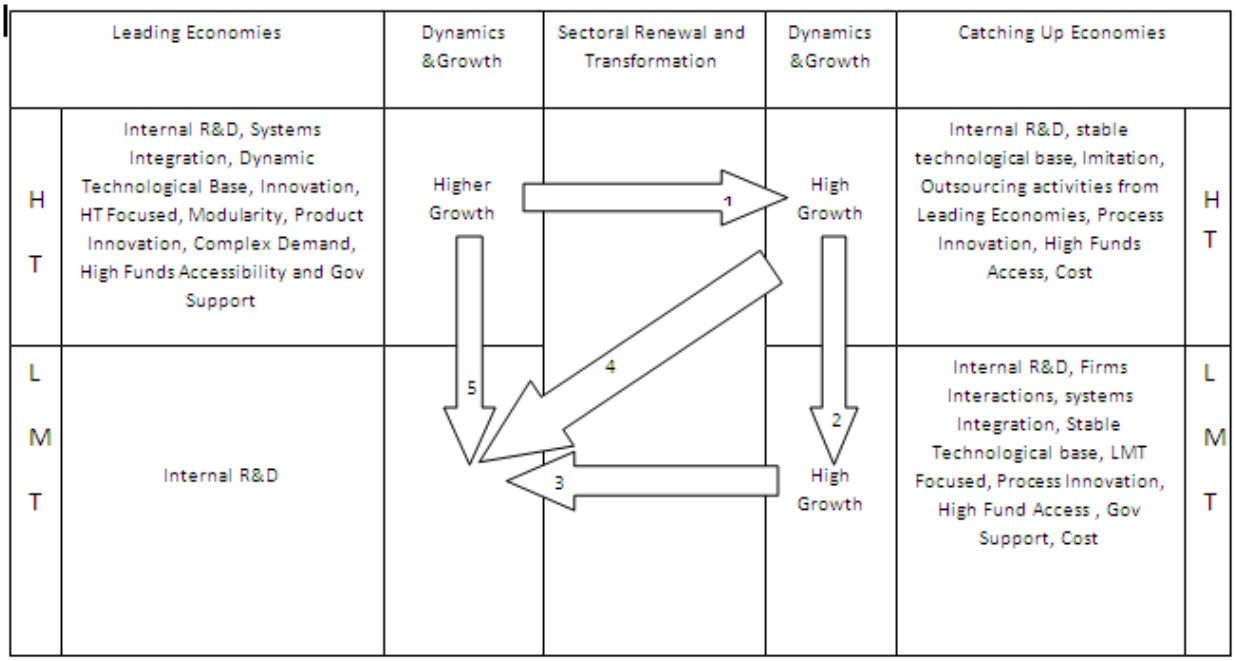


Figure 2 - Conclusion LMT, HT, Leading and Catching Ups

Figure 2 shows the various dynamics affecting each sector and each economy. Arrows represent the dynamics. Breakthrough innovations and technologies are commercialized to the HT sectors in catching ups (Arrow 1). Catching ups imitate the high techs produced in leading economies, and proceed to process innovation. Due to price competition, and relatively lower cost, these HT stand a higher chance of penetrating LMT in both catching ups (Arrow 2) and leading (Arrow 4). Due to the extreme focus of catching ups on LMT, and the process of migration of LMT from developed to developing countries, catching ups stand higher chances of commercializing their LMT products with the LMT of leading countries (Arrow 3). While HT in leading economies can provide high quality technologies to the LMT in the same economy (Arrow 5), it is more probable that those technologies and products are acquired from catching ups due to lower cost, and the increasing product quality.

Conclusion, Limitations and Future Research Work

The prime aim of this research work is to differentiate HT and LMT between firms in leading and in catching up economies. The research work proposed a theoretical framework based on Sectoral Systems of Innovation (SSI) and National Systems of Innovation (NSI). This framework included knowledge and technologies, actors and networks, institutions, sectoral dynamics and growth, and finally, sectoral transformation. Our results show that firms in leading economies are generally more focused on HT, while catching up economies are focused on both, however with a stronger focus on LMT. Firms in catching up economies rely on a stable technological base in all sectors, while HT firms in leading economies are witnessing a rather more unstable, dynamic

technological base. This suggests that, with respect to HT, leading economies could be considered the innovator, while catching ups are the imitators. Furthermore, HT in leading economies relies on product modularity to outsource various components probably to firms in catching up economies. In contrast, LMT, which does not demand extensive innovative capabilities, is led by firms in catching up economies who master process innovation.

This technologically driven race did not emerge by chance. Our study shows that catching ups are putting greater emphasis on universities to produce knowledge. In addition, we found that catching up economies provide higher accessibility to funds in order to grow the various industrial sectors, specially the LMT. This focus on LMT and export empowered the role of institutions that in turn play a key role to expand their global market share. Consequently, the role of institutions and governments with respect to regulatory policies, intellectual property protections are of high importance to firms in catching up economies, especially in LMT.

As a result to those important steps the various agents in catching up economies have undertaken, sustainable growth is achieved, notably in the LMT. In contrast, the same growth is witnessed for the HT, with respect to firms in leading economies. While it could be argued that catching ups are mastering LMT, evidence suggest that extensive efforts are put into HT as well using cost based strategies. Moreover, our general results suggest that catching up countries are strategizing for this sectoral evolution, renewal and transformation process, for both sectors however with a stronger emphasis on the LMT. These results call for a renewed international industrial policy that takes into consideration the various changes in the global markets, supported by Aiginger (2007), and the various OECD (2006, 2007, 2010) economic survey reports. One limitation of the analysis is that within groups of course differences exist. For instance, while Taiwan and South Korea are put in the same group, some differences exist between both economies, as found in Wang's (2007) work.

Our present results are limited by the collected cross-sectional data that does not give any historical or chronological aspect allowing the study of the evolution of the various characteristics in the studied context. Our future research work will adopt evolutionary models of change to understand the evolution and transformation of both sectors, with respect to leading and catching up economies.

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