**“Technological specialization, structural change and market integration”[[1]](#footnote-2)**

Ana Urraca Ruiz[[2]](#footnote-3)

**Resumo.**

Este trabalho explora as relações entre as bases tecnológica e produtiva. O artigo tenta mostrar que, ao longo dos processos de integração de mercados, em que são esperadas mudanças nas estruturas produtivas, mudanças na especialização tecnológica se devem menos à oportunidade tecnológica e à cumulatividade. A partir de dados para 15 países europeus e 4 latino-americanos, o trabalho conclui que a integração de mercados está associada com elevados ritmos de *catching-up* e convergência, assim como com menores níveis de especialização. Além do mais, há evidencia de que a concentração dos esforços nacionais em inovação não são sempre persistentes. Uma parte razoável das novas competências construídas não são conseqüência de processos cumulativos e, por tanto, há razões para pensar que uma parte relativamente importante da mobilidade e da mudança nos padrões de especialização está associada com mudanças na estrutura produtiva.

**Abstract.**

This paper explores the relationships between technological and productive structures. The paper attempts to show that, along market integration processes, when changes in productive structures are expected, the changes on national technological specialization are less linked to technological cumulativeness and opportunity. The paper uses patent data for 15 European and 4 Latin-American countries. The paper concludes that market integration is associated with elevated rhythms of catching up and converging, and also with lower levels of specialization. Besides that, there is evidence that the concentration of innovative efforts is not always persistent. A reasonable part of the new built competences are not the consequence of cumulative processes and, therefore, there are reasons to think that quite a large part of mobility is strongly associated with productive structure change.

**Palavras-chave;** Cambio estrutural, especialização tecnológica, convergência, integração de mercados

**Keywords;** Structural change, technological specialization, convergence, market integration

**Área ANPEC;** Economia Industrial e da Tecnologia

**Classificação JEL;** O30, O52, O54

**“Technological specialization, structural change and market integration”**

**Introduction**

The nineties represented a crucial decade in UE and Latin American integration processes. In the technological scenario, Transnational Corporations increased their extra-frontier technological efforts and brought up new organizational modes to manage internationalized R&D. At the same time, countries changed their National Technological Specialization (NTS) patterns. During this decade, the European Union became a Monetary Union; America registered different processes of commercial integration like MERCOSUR, NAFTA or the ‘Pacto Andino’ and Brazil, the giant of Latin America, began a slow and growing process of commercial liberalization; Eastern Europe opened its markets after the ‘Berlin wall fall’ and, in Asia, the new tigers (China, India and South Korea) began to increase aggressively their presence in the international markets. Finally, also in this decade, the Uruguay Round negotiations were recovered under the recently created WTO with the aim to establish a progressive liberalization of world trade of goods and services. Along these processes, many of these economies registered deep structural transformations in their productive bases and export structures that have been widely studied (Dalum et al, 1998; Song Tan and Ee Khor, 2006; Shafaeddin, 2005; Meyer, 2008).

Given the importance of technical progress on the long term rate of growth, literature has been developing several theoretical and empirical works on the determinants of NTS and on its persistent versus dynamic character. NTS distributions are neither random nor indifferent to long term growth and can be a strong determinant of long term growth and explain the persistence of development and technological gaps over time (Montobbio and Rampa, 2005). But there is no theoretical or empirical works to associate the integration phenomena to changes in NTS patterns considered as a dimension of structural change. Under the hypotheses that the increasing integration processes from nineties must have provoked deep structural transformations in countries, this work proposes: 1) to estimate the main changes observed in NTS and convergence for UE and Latin American countries between pre and post-integration periods; and, 2) to assess the extent to which mobility can be a phenomenon associated with structural change that usually accompany the integration processes.

1. **Technological specialization and market integration.**

NTS represents the regularity of a national technological activity across fields of knowledge, that is, national technological competences. Specific distributions of national technological competences and capabilities are the result of three sets of forces: i) forces of *autonomous character*; ii), forces of *structural character*; and ii) forces of *induced character*, represented by the National Innovations Systems.

The *autonomous forces* of technical change are the elements that compose the ‘technological regimes’, those are appropriability, cumulativeness, opportunity and demand (Dosi, 1988; Cohen, 1995). Technological accumulation explains the ‘continuity’ of technical change and the stability of NTS patterns. Given that each technology has specific knowledge bases, the direction of technical change will depend on the way each country acquire and accumulate new knowledge over their previous bases of knowledge, that is, its pattern of learning and its absorptive capacity (Malerba, 1992; Malerba et al (1997); Malerba and Montobbio, 2003; Cohen and Levinthal, 1990). The idiosyncratic and specific character of knowledge accumulation processes make the evolution of technical change constrained by path dependency. In the presence of international barriers to diffusion, knowledge spillovers acquire an accentuated national character. This could conduct countries to lock-in and ‘technological persistence’, that is, the future reproduces the past and small initial differences can drive to divergence between countries’ NTS and to unequal rates of growth among countries with an elevated degree of irreversibility (Mancusi, 2001). Persistence explains why NTS remain stable along time, especially in technical fields with feeble specialization (Mancusi, 2001; 2003). Under this approach, NTS is explained by a “unique historical process” and not by relative factor endowments (Stolpe, 1995).

 Technological opportunity represents a force towards mobility. The opening of windows of opportunity in technical change and the emergence of new micro-paradigms in the international scenario can stimulate the full advantage of national competences driving to a re-allocation of resources from some technologies to others, that is, to *mobility*. Empirical evidence confirms only partially the theoretical propositions. Large countries really seem to be associated with greater levels of persistence. Mobility across technological fields is high and asymmetric across technical fields, that is, it is more difficult to increase specialization in technological fields where there is previous disadvantage but it seems to be easier to change the NTS in technical fields related to previous advantages, transforming strong initial specializations into diversification (Mancusi, 2001).

This effect of technological opportunity on NTS has led to the idea that ‘correct’ or ‘wrong’ initial specializations can determine future profiles of specialization and technological dynamism. Correct specializations are related to technologies with high degree of pervasiveness or to technological fields with fast rate of growth of patents along time, this is, with elevated technological opportunities (Huang and Miozzo, 2004; Meliciani 2002; Montobbio and Rampa, 2005). Specialization in this kind of technologies represents some advantages for technological dynamism for having a greater potential for application of new scientific and generic knowledge in other activities (pervasiveness) and for developing of further learning processes (Huang and Miozzo, 2004). At the same time, specialization in ‘inferior’ technical fields (low opportunity) would present some difficulty to move to ‘superior’ technical fields (high opportunity), especially if there is not a proper institutional framework and public policies to stimulate the ‘social process of learning’ (Vertova, 2001; Jungmittag, 2004). Nevertheless, empirical evidence shows that despite initial unfavorable specializations, countries can register high technological dynamism by imitation and catch-up provided that some efforts be undertaken (Laursen, 1999; Meliciani, 2002).

‘Demand’ has been neglected as explicative factor of NTS. Nevertheless, demand determines the knowledge trajectories because it affect the incentive to perform innovations (Cohen, 1995:214) and because it is in fact a powerful selection mechanism (Dosi, 1988). Commercial integration processes may create new markets and destroy old ones, changing expectations over the growth of different markets. These changes should re-allocate resources to innovation towards those technologies where the expected profitability of innovation expenditures is higher. In addition, market integration may foster changes in economic environments and, as a consequence, market and non market selection mechanisms should change as well (users requirements, consumer habits, regulation, etc.).

The structural factors came from the relationships between the *technical structure* and the *productive structure*. Both structures are surely interconnected. On the one hand, industries differ in the allocation of R&D resources and results. So, countries with superior technical base tend to be more specialized in knowledge-intensive industries while countries with inferior technical base tend to be more specialized in labour-intensive industries (Stolpe, 1995: chapter D). On the other hand, technical base is connected with productive base in the extent that the productive base defines specific bases of knowledge for each industry, because it is related to specific products and productive processes (Malerba and Montobbio, 2003). Over these bases of knowledge, technological competences are built. Spillovers between technologies are also connected with the industrial interactions, given that the productive chains share high technological complementarities. Finally, interactions between innovators are highly related to the interactions between competitors in so many ways: collaborative agreements, joint-ventures, first-mover advantages and market power, etc. are good examples of it.

Considering the strong links between productive and technological structures, it is plausible that impacts of market integration on productive structure have some reflection on technological structure for several reasons. Firstly, the theories on international trade predict that commercial integration should change the national productive structure, making countries more specialized in those activities where they already have productive advantages usually linked to factor endowment advantages. As the technical base accompanies the productive base, it is expected that the country registers also mobility towards the technologies that compose the technical base of the new productive base. This kind of movement is especially expected in small economies, which are already very specialized. If this phenomenon happens in all countries, the total effect will be more specialization with convergence, if specialization is in the same technical fields, or with divergence, if specialization is in different technical fields[[3]](#footnote-4). Secondly, according to Stolpe (1999: chapter D), under open market environments, allocation of resources in R&D activities can respond to changes in the factor endowments relative to the trading partners by “shifting the pattern of specialization to those activities for which factor endowment relations constitute a source of a comparative advantage”. Thirdly, integrated markets make easier the access to knowledge and technologies, facilitating the technological catch-up. Imports of incorporated technologies in goods become cheaper and direct investment flows can be accompanied by technology transfer between multinational corporations units across countries (Camerona et al., 2005). Catch-up would become more accelerated, especially in countries with lower level of technological development. A faster process of catch up can even drive these countries to develop technological competences in new fields of knowledge and in their related fields and, so, to a higher level of technological diversification, pushing them to converge with leaders. Both effects can happen simultaneously. Given that both follow opposite directions, it would be necessary to establish measures to identify which is more important and which prevails over the other.

As a last effect, the path of specialization in technology can follow the path of specialization in production along the process of technological development and growth. It has been tested empirically that productive specialization moves on different stages along the process of economic growth following a U-curve format (Imbs and Wacziarg, 2003). At the beginning, countries are strongly specialized in a few productive activities. Countries become progressively more diversified as their industrialization process advances. But when the industrialization process matures, countries reverse the tendency, becoming more specialized again. Some of these effects can be also expected to take place when the process of catch-up, stimulated by market integration, accelerates the technological development in follower countries. Initial stages of technological development correspond to high specialization in a very few technical fields and high de-specialization in so many technical fields. This performance must change as countries progressively achieve higher levels of technological development (by catch-up progress or by internal leaderships) and a more diversified productive base. Therefore, a rise of the technological diversification is expected. But as technological opportunities are exhausted or matured, it would be possible a return to the concentration of specialization initiating a new cycle in the pattern of specialization from new technological opportunities.

Finally, National Innovation Systems (NIS) and Technology Policies represent *the induced explicative factor* of the NTS evolution. NIS are embedded of cultural, historical and social aspects that are highly specific for each country. Idiosyncrasy of NIS also reflects the specificity of national learning and innovation processes, what can be an explanation for the persistence of technological gaps along time. Technology Policies are able to re-allocate resources to innovation and to create absorptive capacity in fields of knowledge where countries hold weak capabilities, making technological catch-up possible. That can explain unexpected movements from some technologies to others (Mancusi, 2003; Vertova, 2001; Brusoni and Geuna, 2003).

1. **The data sources**.

This work uses patent data filed in the European Patent Office (EPO) between 1980 and 2008. Patents are largely used by literature to analyze technological competences at national (and firm) level because they represent results of formal or informal innovation efforts. They provide detailed data in a regular and long time series that may be grouped by firm, country, geographic location or technical fields (Patel and Pavitt, 1991). But there are also some limitations of patent data as a source of information to build indicators on national technological specialization and to analyze the technological transformation as a part of structural change. Firstly, patents reveal distributions of competences across technical fields but not distributions of capabilities in the Archibugi and Coco’s (2005) sense. Measures of capabilities should include indicators on Embodied and Disembodied knowledge, Codified and Tacit knowledge and Generation and Diffusion of knowledge. Patent deposits only give information on disembodied technologies and codified knowledge. So, even under the assumption that it does exist complementarities between all three categories, the only use of patents underestimates the set of aspects that transform a competence into a capability. Secondly, patents underestimate the contribution or closeness of scientific bases to the creation of the technical bases because of “the lack of engineering capabilities to embody scientific results in profitable products” (Brusoni and Geuna, 2003). By the opposite, it is possible that a country have strong competences and capabilities in development weakly supported by basic knowledge (*ibidem*). Thirdly, measuring technological specialization to the development of specific products and industries can involve a classification of technological fields that does not respond to the usual ones in patent classifications. And fourthly, some national technological competences can be underestimated when they are built on non patenteable technologies (or bases of knowledge) or on technologies that are not protected by patents.

EPO database presents some advantages when compared with UPSTO (American patent office) for international comparisons (Le Bas and Sierra, 2002; Grupp and Schmoch, 1999; Zeebroeck et al, 2006). Firstly, EPO is the most internationalized patent office in the world, because a simple patent is extensible to all Munich Convention member countries. This means that there is no country bias, that is, there is no ‘domestic effect’. UPSTO is only valid in United-States territory, which introduces domestic bias to the USA market. Secondly, fees applications are relatively higher in EPO. This acts as an economic filter and eliminates low industrial value patents. Thirdly, EPO publishes grants and deposits of patents eighteen months after the application (by mean), while UPSTO only publishes after two years (by mean).

Three major methodological aspects worth to be noted: 1) patent *applications* have been used for statistical reasons (see Mancusi, 2003); 2) the inventor residence gives the nationality to the patent; 3) although some works select only patents filed by firms to estimate NTS (for example Mancusi (2001) and (2003)), this work includes all the patents independently of who the applicant is. This is due to the assumption that national competences are built by the whole national efforts, including universities, public research centers, government agencies and independent inventors (Brusoni and Geuna, 2003).

The European countries are those defined as UE-15. Belgium and Luxemburg have been aggregated as one single country (Bel-Lux). The pre and post integration periods were 1985-1993 and 2000-2008 respectively. To tackle the Latin American case, the paper analyzes Argentina, Brazil, Mexico and Chile. Other countries were disregarded due to the small number of deposits in EPO. The pre and post integration periods for AL-4 were 1980-1994 and 1999-2008. The choose for the periods attended two criteria: to account a significant number of patents and the transition towards a higher level of integration in the international markets. The area of reference for European countries is the aggregation for UE-15 and for Latin American and Asian countries is the whole world.

1. **Testing changes in technological structures under market integration**

Shift-share analysis is a tool that permits to evaluate the changes of the relative position of a country´s growth with respect to a set of countries and to decompose that growth by components. In terms of technological dynamism, the decomposition of the growth of patents share allows to identify: (i) some evidence on changes in technological structures between two period of time; (ii) the role of technological opportunity (TO) to guide the direction of technological efforts; and (iii) the extent through which the technological dynamism is characterized by movements across technological fields according to the dynamicity of their technological opportunity. Denoting *pj* as the share of patents of the *j*-country in the world; *pij* as the share of patents of the *j*-country in the *i*-technical field over the same technical field in the world; *oi*, the share of patents of the *i*-technical field in the world; *sij*the patents share distribution of the *j*-country by *i*-technical fields and (t-1) the initial period of analysis, the growth of the patent shares between two periods can be decomposed as follows;

$$\dot{\dot{p\_{j}}=\sum\_{i}^{}s\_{ij}^{t-1}\dot{p\_{ij}}}+\sum\_{i}^{}s\_{ij}^{t-1}\dot{o\_{ij}}+\sum\_{i}^{}s\_{ij}^{t-1}\dot{p\_{ij}}\dot{o\_{ij}}$$

According to Laursen (1999) if the growth of patents is a proxy of technological opportunity, the decomposition of TO in technology share effect, structural technology effect and technology adaptation effect allows the measurement of the access of a country to sectors with high levels of technological opportunity. The first factor $\sum\_{i}^{}s\_{ij}^{t-1}\dot{p\_{ij}}$ represents the ‘technology share effect’ and measures the fraction of growth due to the dynamism of patenting activity strictly (technological activity in the wide sense), keeping constant the weight of the technical field in the initial period. The second factor $\sum\_{i}^{}s\_{ij}^{t-1}\dot{o\_{ij}}$ measures the “structural technology effect”, or the fraction of growth due to a ‘correct’ (or ‘incorrect’) pre-integration specialization pattern. That is, if the country took advantages for being previously specialized (or de-specialized) in technical fields that were dynamic (or stagnated) between periods. As $\dot{o\_{ij}}$ represents a measure of technological opportunity, this factor can be interpreted as a measure of the technological opportunity contribution over the growth of the national share of patents. The third factor $\sum\_{i}^{}s\_{ij}^{t-1}\dot{p\_{ij}}\dot{o\_{ij}}$ shapes a residual effect called ‘technology adaptation effect’. It takes negative values when the country left high OT fields (or went into staged OT fields); and takes positive values when the country went into high OT fields (or went out staged OT fields). That factor represents a measure of the contribution of the mixed effect of technological opportunity and patenting activity (in the strict sense) to the patent share growth.

European countries were classified in three different groups: leaders, whose pre-integration share of patents was superior to 10%; medium technological level, whose pre-integration share of patents was between 1% and 10%; and delayed countries, whose pre-integration share of patents was inferior to 1%. Even though this classification has not considered the country size, it is compatible with other criteria like P&D intensity or number of patents by people.

European leaders reduced their share of patents between pre and post-integration periods, specially France (-13,8%) and Great Britain (-21,8%). This was a consequence of the fall observed in the ‘technological share effect’. Germany also shows a loss in its share of patents, but it was due to the structural effect, that is, it had a ‘wrong’ initial specialization in technological fields that remain stagnant between periods. UE Medium technological levels show moderate rates of growth in their shares of patents. The more dynamic cases were Finland (91,0%) and Denmark (62,0%). The technological dynamism is the main responsible for this tendency which compensated the negative effect of an adverse initial specialization in the cases of Austria, Belux and Italy. In Finland, the adaptation effect was also quite relevant, which means that the country re-oriented its technological efforts towards more dynamic areas, giving up those with low OT. The Delayed UE-countries show a strong growth of their share of patents, which is especially relevant in Portugal (215,8%). This result is consequence of a combination of strong technological dynamism and of taking advantage of their initial specialization, which compensate the negative value of the adaptation effect of all four countries.

Latin American countries register also high growths of their share of patents in the world, mainly Chile (138,2%) and Brazil (126,0%). The technological effect is the main explanatory driver for this high dynamism compensating their unfavorable initial specialization. Mexico also shows high rates of growth with respect to both areas of references: the whole world and NAFTA (121,0% and 113,8% respectively). In the four countries the adaptive effect is negative. This finding means that the technological dynamism did not take advantage of the dynamicity of the high TO fields. By the contrary, all the countries tended to move towards more stagnant technological TO fields or to leave the most dynamic ones.

Table 1. – Growth of the patent shares between periods and decomposition of growth by shift-share analysis.

|  |  |  |  |
| --- | --- | --- | --- |
|  |   | Patent share growth | Components of growth |
|   |   | Technological | Structural | Adaptation |
| UELeaders | Germany | -1,70 | 0,34 | -3,66 | 1,63 |
| France | -13,85 | -16,82 | 5,62 | -2,64 |
| Great Britain | -21,79 | -25,67 | 6,52 | -2,64 |
| UE-Medium technological level | Austria | 10,28 | 19,19 | -7,61 | -1,29 |
| Belgium-Lux | 28,30 | 38,94 | -6,84 | -3,79 |
| Italy | 5,36 | 14,92 | -3,84 | -5,71 |
| Netherlands | 16,41 | 14,80 | 0,55 | 1,06 |
| Sweden | 10,09 | 2,59 | 2,54 | 4,96 |
| Denmark | 62,08 | 56,81 | -0,44 | 5,71 |
| Finland | 91,02 | 46,37 | 9,77 | 34,87 |
| UEDelayers | Spain | 140,19 | 144,15 | 2,42 | -6,38 |
| Greece | 97,33 | 100,77 | -0,27 | -3,18 |
| Ireland | 101,80 | 83,75 | 22,30 | -4,25 |
| Portugal | 215,87 | 196,66 | 22,26 | -3,05 |
| Latin America | Mexico (W) | 121,03 | 149,93 | 9,01 | -37,91 |
| Argentina | 109,39 | 106,66 | 7,61 | -4,87 |
| Brazil | 126,03 | 148,89 | -2,68 | -20,18 |
| Chile | 138,17 | 214,99 | -7,32 | -69,50 |
| Mexico (NAFTA) | 113,78 | 171,00 | 8,66 | -65,87 |

Source: EPO, Space Bulletin 1978-2008 and own elaboration.

The three components of the shift-share analysis can be used to estimate the role of technological opportunity on structural technological change and technological dynamism. The Pearson correlation of Structural Effect with Total and Technological Effects permits to know if initial correct or incorrect positions can be associated to the future technological dynamism and patenting activity respectively. The Pearson correlation of Adaptation Effect with Total and Technological Effects tells about how the technological dynamism and patent activity is associated positively with movements towards fields of dynamic OT or negatively to movements towards stagnant OT fields. Finally, Pearson correlations between Structural and Adaptation effects measure the degree of association between initial ‘correct’ or ‘wrong’ and movements towards the ‘correct’ or ‘wrong’ technological fields.

The results show that there is no significant association between the Structural effect and Total-Technological effects (table 2). In developing countries, apart from not significant, the signal became still negative. Only for EU15 countries, the structural effect is significantly associated to Total and Technological effects. Along with Laursen (1999)’s findings, those results mean that, even with ‘wrong’ initial specializations, catch up really happens and high levels of technological dynamism can be achieved. So, it seems that the role of absorptive capacity (in terms of the level of qualification of human capital and technical-scientific infrastructures (Castellaci, 2008)) should prevail over initial NTS patterns as a driving force of convergence. Catch-up can still be stimulated by the possibilities that emerge in integration processes, reducing the effects of technological determinism.

Table 2. Association between structural effect and dynamism. Pearson correlation indexes

|  |  |  |  |
| --- | --- | --- | --- |
|   | Structural Effect with.. | Adaptation Effect with .. | Adaptation with Structural Effect |
|   | Total Effect | Technological Effect | Total Effect | Technological Effect |
| Total countries\* | 0.3547 | 0.1433 | -0.3173 | -0.5881 | 0,1633 |
|  *P-value* | *(0.1362)* | *(0.5582)* | *(0.1856)* | *(0.0081)* | *(0.5041)* |
| EU15 | 0.4617 | 0.3168 | 0.0703 | -0.0967 | 0.0707 |
|  *P-value* | *(0.0832)* | *(0.2500)* | *(0.8034)* | *(0.7316)* | *(0.8024)* |
| EU15+AL4 | 0.0715 | 0.0227 | 0.7744 | -0.6792 | 0.1254 |
|  *P-value* | *(0.7340)* | *(0.9144)* | *(0.0000)* | *(0.0002)* | *(0.5505)* |

 \*; includes also six Asian countries: China, Singapure, Hong-Kong, India, Taiwan and South Korea.

Source: Space bulletin EPO 1978-2008 and own elaboration

Adaptation Effect is positive and significantly associated with Total Effect and negative and also significantly to Technological effect. That means that positive association exists between the ‘correct’ direction of technological efforts and the growth of patent share. But it also means that the direction of technological efforts is negatively correlated with the dynamicity of the technological efforts, this is, countries that performed higher rhythms of patenting activity tended to move towards stagnant TO technical fields or to go out from dynamic TO ones. That observation is still quite stronger in European Delayers and Latin-Americans. Only in UE15 countries the association between this kind of efforts is no significant (table 2). The Pearson coefficient between Adaptation and Technological effects takes a positive and significant signal when tested for Asian plus European countries. This means that, in this case, the technological dynamism is positively associated with movements towards dynamic OT fields or from the stagnant ones.

Finally, data show that there is no significant association between Structural and Adaptation Effect in any context. Taking advantages because of an initial ‘correct’ position is not necessarily linked to higher efforts in patenting activity in the same direction. So, it seems that countries moved towards technological fields where they could explore internal endowments more than towards those that permitted to explore technological opportunities. And, as a consequence, some paradoxical results can be observed; countries with ‘wrong’ initial positions (higher initial shares in stagnant TO fields) were able to move to fields with high TO and countries with ‘wrong’ directions were able to register high dynamism by an extraordinary patenting activity. This finding shows that technological opportunity did not configure a major factor to explain technological movements along the market integration processes and strengthens the idea that the construction of capabilities prevails over the technological determinism as determinant of the rhythms and paths of technological development.

1. **Analysis convergence between pre and post integration periods**

The shift-share analysis drove to the intuitive conclusion that, at least in aggregate terms, economic integration led to technological convergence between countries: higher dynamism is observed in followers and stagnation is observed in leader countries. But does it means that countries are becoming more similar?. If country specializations are getting more similar, the international patterns of technological performance is characterized by competition. If they are getting more dissimilar, the performance is characterized by complementarity and cooperation (Archibugi and Pianta, 1994).

Technological convergence in terms of similarity will be assessed by a measure of distance represented by the chi-square, (χ2 ), calculated as χ2 = ,where *pij* is the j-country share or patents in i-technical field and *piw* is the share of patents in the same technical field for the area of reference (Archibugi and Pianta, 1992: chapter 8; Pianta and Meliciani, 1996). This indicator takes value 0, in the case of total similarity (convergence), and higher positive values as sectoral distributions become more dissimilar (divergence).

**Graph 1.- Evolution of χ2**  **before and after monetary union. UE-15 by groups.**

Source: Space bulletin EPO 1978-2008 and own elaboration**.**

**Graph 2.- Evolution of χ2**  **before and after monetary union.UE-15 and Latinamerica**

Source: Space bulletin EPO 1978-2008 and own elaboration

The results are reported in Graphs 1 and 2. Leader countries increased moderately their distances with respect to the UE-15[[4]](#footnote-5) area after the integration, going from a mean value of 0.13 to 0.17. Germany and France registered small differences. Great Britain showed the greatest increase in distance from 0.19 to 0.28. Medium countries show a moderate aggregate tendency towards convergence, which hides opposite tendencies by country. Austria, Bel-lux, Finland and Sweden followed convergence paths; Netherlands and Italy followed a divergence trajectory and Denmark remained its position. Delayed countries showed strong path to convergence, specially high in Portugal. The initial level of technological activity of Portugal was very low and involved in a very few number of technical fields. Thus, some low performance activities represented high shares by of the country’s total effort diverging in respect to UE-15. After integration, Portugal distributed its technological activity across a larger number of technical fields and this allowed it to reduce significantly its distances towards the reference area (Graphs 1 and 2).

Latin American countries show tendencies to convergence, although with different intensities. Chile’s large distance from the world reference (35.2) was reduced almost to half of its initial value (19.2). Argentina and Mexico, with lower initial distances, also diminish their aggregate differences with the world, going from 8.9 and 7.9 pre-integration values to 2.4 and 3.7 post-integration values respectively. Brazil did not register significant changes, going from an initial value of 2.8 to a final value of 2.6.

Table 3. Association between convergence and technological dynamism.

|  |  |
| --- | --- |
|   | Pearson correlation indexes of χ2 with: |
|   | Total Effect | Technological Effect | Structural Effect | Adaptation Effect |
| EU15 | -0,753 | -0,716 | -0,461 | -0,164 |
|  *P-value* | *(0,002)* | *(0,004)* | *(0,097)* | *(0,576)* |
| EU15+AL4 | -0,746 | -0,678 | -0,405 | 0,184 |
|  P-value | *(0,000)* | *(0,002)* | *(0,095)* | *(0,464)* |

Source: Own elaboration.

In sum, it seems to have some evidence that convergence is associated to technological dynamism. In order to have a better vision of this probable association, table 3 presents Pearson correlations indexes between χ2’s rate of growth and the components of the share of patent growth. The negative and strongly correlation between the χ2 rate of growth and the technological effect means that increases of technological dynamism is associated with negative χ2 rate of growth, which proves the positive association between convergence and dynamism. A negative correlation between χ2 rate of growth and the structural effect means that a more favorable initial specialization corresponds to negative χ2 rate of growth, that is, to convergence. The dynamism of TO over specific technical fields is pushing up follower countries to more similar distributions with respect to leaders, strengthening convergence processes. As expected, a “correct” initial position favored convergence, what is reflected in the negative signal coefficient of correlation with the structural effect, which is also quite significant. Finally, the positive association between χ2 rate of growth and adaptation efforts means that movements to dynamic TO fields (or from stagnant) corresponds with positive χ2 rate of growth, this is, divergence. And a movement towards stagnant TO fields (or from dynamic) corresponds with negative χ2 rate of growth, this is, convergence. When this happens, it can be explained by the strength of catch-up process. Even when most of the follower countries remain or go to stagnant technological fields, they converged with their technological reference areas because the catch-up process was so powerful that passed through a lot of new technical areas that began to be developed. Nevertheless, the coefficient is not significant for the both samples it was calculated.

1. **Evolution in specialization patterns: mobility and persistence**.

The usual indicator to measure specialization is Revealed Technological Advantage (*RTAij*), calculated as $\frac{p\_{ij}}{p\_{iW}}$, following the previous notation. This indicator reveals positive specialization when it takes values superior to one and non-specialization when it takes values between zero and one. An aggregate measure of specialization for each country is the variation index (*Vj*) (standard error over mean) of the *RTAij*. The higher *Vj* is, the higher the dispersion of *RTAij* around the mean will be and, so, the higher the concentration of specialization.

The data show a quite strong tendency towards specialization in all three European leaders (table 4). In medium tech-level countries, it is observed a prevalence of moderate changes towards an increase of specialization (Italy, Netherlands and Denmark) and a moderate tendency towards diversification in the rest of the countries. The Delayers show a strong tendency to diversification, only moderate in Greece.

Latin American countries show a general and strong tendency to diversification. Only Brazil follows a path of specialization. These evidences confirms the hypothesis of the evolution of the technological level of specialization, characterized by specialization-diversification-specialization along the technological development process. In fact, countries that began the period with high levels of specialization trended to become more diversified and *viceversa*. The Pearson correlation index between initial *Vj* values and *Vj*growth was significant and equal to -0,829. To test the relationship between the technological dynamism and the pattern of evolution of technological specialization, it was correlated the rate of growth of de *Vj* values to the rate of growth of the share of patents between periods for all countries. The Pearson index was large, negative and significant (-0.723), which means that higher technological dynamism is quite associated with lower levels of specialization.

Table 4. Rate of growth of *Vj* by groups of countries

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   |   | Before | After | Rate of growth (%) |
| UE Leaders | Germany | 0,2045 | 0,2525 | 23,48 |
| France | 0,3968 | 0,4366 | 10,04 |
| Great Britain | 0,4178 | 0,5186 | 24,11 |
| UE Medium technological level | Austria | 0,7416 | 0,7090 | -4,39 |
| Bel-Lux | 1,2032 | 1,1196 | -6,95 |
| Italy | 0,6235 | 0,6576 | 5,47 |
| Netherlands | 0,7911 | 0,8949 | 13,13 |
| Sweden | 0,7864 | 0,6872 | -12,61 |
| Denmark | 0,9832 | 1,0771 | 9,55 |
| Finland | 1,4488 | 1,4129 | -2,48 |
| UE Delayers | Spain | 0,7509 | 0,6232 | -17,01 |
| Greece | 1,8306 | 1,7539 | -4,19 |
| Ireland | 1,6797 | 1,0634 | -36,69 |
| Portugal | 3,9480 | 2,0158 | -48,94 |
| Latin American | Argentina | 2,8662 | 1,5830 | -44,77 |
| Brazil | 1,5160 | 1,6997 | 12,12 |
| Chile | 5,1439 | 2,4450 | -52,47 |
| Mexico | 2,6467 | 2,3026 | -13,00 |

Note: 3-digits aggregation level. Source; EPO and own elaboration.

The analysis of mobility and persistence helps to understand the evolution of specialization patterns. Mobility is measured by the percentage of sectors that changed position from non-specialization to specialization or vice-versa for a 3-digits level of aggregation (120 technological classes). Persistence is measured as the percentage of sectors which specialization or des-specialization remained. Data results confirm the theoretical background on the persistence phenomenon and its higher importance over mobility as explicative factor of the stability of the specialization patterns. However, some relevant facts can be observed (table 5): i) in aggregate, persistence prevails over mobility for all groups of countries; ii) persistence in de-specialization is very much higher than persistence in specialization, especially in European Delayers and Latin American countries; iii) mobility (both, to specialization and to des-specialization) is at least as relevant as persistence in specialization at 3-digit level of aggregation; iv) the relative importance of mobility rises as the level of technological development assumes lower values. For European followers and Latin American countries, mobility to new technological fields is a more relevant phenomenon than persistence in their specialization pattern dynamics.

Table 5. Mobility and persistence of specialization (%).

|  |  |  |
| --- | --- | --- |
|   | Mobility | Persistence |
|   | Entry | Exit | Total | De-Spec. | Special. |
| *European Leaders* | 13,33 | 14,44 | 27,78 | 45,00 | 27,22 |
| France | 13,33 | 16,67 | 30,00 | 41,67 | 28,33 |
| Germany | 17,50 | 13,33 | 30,83 | 34,17 | 35,00 |
| Great Britain | 9,17 | 13,33 | 22,50 | 59,17 | 18,33 |
| *European Mediums* | 10,36 | 13,93 | 24,29 | 49,29 | 26,43 |
|  Austria | 10,00 | 10,00 | 20,00 | 38,33 | 41,67 |
|  Bel-Lux | 10,00 | 6,67 | 16,67 | 59,17 | 24,17 |
| Denmark | 6,67 | 14,17 | 20,83 | 55,83 | 23,33 |
| Finland | 8,33 | 21,67 | 30,00 | 54,17 | 15,83 |
|  Italy | 18,33 | 10,83 | 29,17 | 35,00 | 35,83 |
|  Netherland | 7,50 | 10,00 | 17,50 | 60,00 | 22,50 |
| Sweden | 11,67 | 24,17 | 35,83 | 42,50 | 21,67 |
| *European Delayers* | 17,08 | 17,92 | 35,00 | 46,67 | 18,33 |
| Greece | 21,67 | 15,00 | 36,67 | 46,67 | 16,67 |
| Ireland | 11,67 | 21,67 | 33,33 | 54,17 | 12,50 |
| Portugal | 18,33 | 18,33 | 36,67 | 52,50 | 10,83 |
| Spain | 16,67 | 16,67 | 33,33 | 33,33 | 33,33 |
| *Latin America* | 20,00 | 16,04 | 36,04 | 47,08 | 16,88 |
| Argentina | 25,00 | 24,17 | 49,17 | 41,67 | 9,17 |
| Brazil | 15,83 | 14,17 | 30,00 | 39,17 | 30,83 |
| Chile | 20,83 | 15,00 | 35,83 | 57,50 | 6,67 |
| Mexico | 18,33 | 10,83 | 29,17 | 50,00 | 20,83 |

Source: EPO and own elaboration.

These findings support the theoretical hypothesis that cumulativeness and path dependence influence patterns of specialization in hindering the development of relevant technological activity and catching-up in technical fields where the country has not previously developed absorptive capacity. But these results also reveal that persistence in specialization does not always prevail over mobility. Mobility can be at least as important as persistence in technologically developed countries and more relevant in catching-up countries, where the patterns of technological specialization are not stable.

Over this last feature, what can theory explain at last? If technological opportunity is not a major expletive factor of mobility, is cumulative knowledge an explicative factor of changes in technological specialization? or, by contrary, is it possible to expect that other mechanisms associated with economic integration and structural change play an essential role in the observed changes? In order to answer these questions, a final empirical exercise on evolution of patterns of technological specialization is undertaking, using technological competence analysis. According to Patel and Pavitt (1997), competences can be classified in Core, Niche, Background and Marginal[[5]](#footnote-6). Core competences represent the technological strengths and Marginal competences represent technological shortcomings. Both, Niche and Background competences represent the potential and the natural trend of technological growth. Niche competences explore technological niches from previous cumulative knowledge and background competences allow the exploration of new technological opportunities and the development absorptive capacity to catch-up. As a consequence, core competences can be built from background and niche competences.

Table 6 shows the results of that approach in persistence and mobility analysis. The first four columns show the weight distribution of each type of competences over the total sectors in each group of countries and in the pre and post integration period. Persistence aggregates the weights of diagonal and mobility the rest of weights. The mobility can be decomposed in three components. The first one, called “Expected mobility” measures the part of mobility that is due to the natural trend of technical change through accumulation and previous learning processes. Expected mobility aggregate the weights registered from niche to core and from background to core or niche. Second and third components are “Not expected” and that can be associated to drastic changes in technological structure. The second component is a positive effect and it refers to the building of central, niche and background competences from marginal competences. Given that this cannot result from either natural trends of technical change or from technological accumulation, it can be only understood as an answer given by private agents to the new technological opportunities emerged in integration process or an answer given by governments consisting in the re-allocation of resources to innovation in new technological fields.

Third component is understood as a ‘perverse’ effect of market integration, consisting in destruction of competences created in the past, which means a real structural change. This effect can emerge from the re-structuring of productive base or from induced technology policies. It is measured as the aggregation of the weights of previous core competences that become niche, background and marginal. Those previous niche competences that became background or marginal; and those background competences that became marginal.

Table 4. Mobility and persistence of national technological competences\* (%)



\*(3-digit level of aggregation). The numbers between brackets are the contribution of each factor to the mobility index.

Source: EPO, Space Bulletin and own elaboration.

The results of table 6 show, once again, that the role of cumulativity to determine some degree of “irreversibility” of technical change is possible, but with some qualifications. Irreversibility is a phenomenon basically referred to persistence in marginal competences. But this kind of persistence does not necessarily involve a constraint for technological development in the long run. A part of the national specialization in this kind of competences appears because countries are not expected to be active in all technical fields, that is, there is a kind of ‘*natural rate of technological inactivity’* that remains over time. This ‘natural rate of technological inactivity’ tends to persist the smaller the country and the more specialized its productive structure is. In other cases, this ‘natural rate of technological inactivity’ can be higher when the path of technological development responds to a strategy of concentration of innovative efforts over specific technical fields. So, these can explain the higher persistence in marginal competences. With much less importance, technological strengths (core and niche) tend to persist in a greater extent in European countries than in Latin American and only persistence of niche competences seems to be positively associated to the level of the technological development. Niche competences persist more in Europeans Leaders and Mediums. Persistence of core competences is smaller and does not carry large differences across groups of countries.

Some empirical findings on mobility are also quite interesting. Mobility is not a depreciable phenomenon when defined in terms of ‘changes of the type of competences’. In European Delayers and Latin American countries, around 40% of technical fields lost their initial characterization. This percentage is lower for the rest of the groups, but still significant (around 32-33%). And once again, mobility is a more frequent phenomenon that persistence in specialization (core plus niche) for all groups of countries and it is characterized by movements between niche and marginal competences.

Mobility is also a phenomenon more associated to structural change motives. Expected mobility is only responsible for around 6-8% of total mobility observed in Europe and about 9% in Latin America. The effect of this structural change is associated with the loosing of previous specialization and destruction of initial advantages. This occurs for all groups of countries and it is much more relevant the weaker the initial technological level. So, for European delayers, 54.5% of its total inter-sectoral mobility consisted in the abandonment of its initial advantages and a new allocation of resources to innovation. In Leaders and Medium technological level this effect is more important (55.5% and 59.0% respectively). In Latin American countries, markets integration was accompanied by the building of new specializations even in technological fields with no previous efforts, which explains 44.9% of total mobility. So, they present a more balanced impact between building and destruction of previous competences.

At least 90% of mobility is “non-expected”, this is, neither due to the taking advantages of technological opportunities nor by the creation of absorptive capacity. That may be an evidence that mobility is probably associated with structural change. Europe is clearly more characterized by the loosing of competences or by a ‘creative destruction processes’. More than 50% of mobility consisted in the loss of initial advantages or capabilities (although different behaviors can be observed by country). And this happened in all groups, becoming more relevant the lower the level of technological development was. So, Latin American countries present a more balanced impact between building and destruction of previous competences.

**Concluding remarks**.

This paper aimed to show that there are theoretical reasons to think that technological structures are changing along integration market processes. And, in the extent that technological structures are closely linked to economic structures, these changes should be considered a part of structural change. A group of countries was chosen to test the principal changes registered in their technological structures between pre and post market integration periods. More specifically, the paper has chosen fifteen European countries that were referred to the pre and post Monetary Union period and four Latin-American countries referred to the nineties liberalization policies, which marked the decade for the openness of their markets and their exposure to higher international competition.

Market integration in UE-15 and AL-4 was companied by technological convergence, that is, a reduction of technology gaps between leaders and followers and more similar share of patents distributions, which means a technological competition performance. This is mainly due to the acceleration of the catching-up process, which was characterized by high technological dynamism that made followers develop new competences. Technological dynamism and diversification were so powerful that movements towards stagnant TO fields (or from dynamic) did not represent a constraint to convergence. The paper also shows that followers before integration had very high levels of technological specialization. After the integration, the technological dynamism of followers was accompanied by greater levels of technological diversification, while leaders became more specialized.

The *shift-share* analysis showed that technological opportunity did not play a significant role to explain the technological dynamism. Initial ‘correct’ specialization does not necessarily conduct to movements in the same direction. By the contrary, countries which registered higher technological dynamism and patent activity used to move to stagnant technologies independently of their initial positioning, this is, their dynamism was not oriented by the enjoyment of advantages provided by movements towards dynamic technologies but by an exploitation of their initial endowment advantages.

Persistence is really a phenomenon more relevant than mobility, but with some qualifications. Persistence is mainly related to de-specialization or, more concretely, it is basically a phenomenon that affects to marginal competences. This kind of persistence does not necessarily have to imply irreversibility. It is expected that countries will not be active in all possible technical fields. Their technological possibilities are constrained by their productive and technical bases. And, even considering that the technical base is wider than productive base, it is plausible to expect that small countries should present a higher ‘natural rate of technological inactivity’ which tends to remain throughout time. Persistence in de-specialization can be also a result of the concentration of national innovative efforts. The question is if, in this case, path dependence constrains future technological developments in the technical fields developed in the past. Data shows that the answer to this question is ‘no’. Mobility from and to specialization is at least as important as persistence in specialization in mature countries (leaders and medium European countries), but in catching–up countries, mobility is more than twice more important (European Delayers and Latin-Americans).

The implications of these findings in the long run are uncertain. It is still early to know the dimension of the consequences of the international financial crisis in terms of the international allocation of resources or modification of national productive bases. It is also difficult to know which will be the responses of governments in terms of markets openness. But following the observed tendencies, it is plausible to think that if there is a closure of international markets, the international technological diffusion and the catching-up processes for follower countries will hinder and lock-in problems will be able to appear. In this case, technological specialization of countries will be more restricted to their internal advantages and technological endowments and it is predictable a tendency to the international polarization of actual national technological specializations.

The findings also permit to visualize the changes of technological structures as a result of both ‘creative accumulation’ and ‘creative destruction’ processes. ‘Creative accumulation’ did not represent a crucial role in mobility between pre and post integration periods, even in most technologically developed countries. On the contrary, ‘creative destruction’ configured the main characteristic of mobility between the considered periods for pre and post market integration. To determine which part of this is due to autonomous factors, to induced factors or to endogenous structural factors is impossible. But it is quite plausible that Creative Destruction is associated to market integration.

Finally, the results characterize different catching-up processes under integration environments in Europe and in Latin American countries. The reasons for that are not completely clear but one can speculate that it is linked to the initial level of technological development and to the trend towards diversification. Traditional theory on NTS patterns does not give enough elements to explain why the diversification paths do not prevail over the previous specialization patterns in the catching-up process. This is a challenge for future works.

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3. According to Archibugi and Pianta (1994), countries tend to be more specialized across a lower number of technological fields. This configures a pattern of technological convergence characterized by ‘complementarity and cooperation’ for technologies in opposition to a ‘substitutability and competition’ pattern, which would happen if countries got more diversified. [↑](#footnote-ref-4)
4. As χ2 is calculated over an area of reference in which the country under comparison makes a part, the larger the country is, more will be affected the area of reference´s sectoral distribution by technical field, and so, the larger will be the similarity between both distributions and the lower the distance will be. A solution for this effect is to estimate the χ2 robustness by comparing the standard deviation of the patent shares distribution by technical fields for each country and respecting to the standard deviation for the area of reference. The higher is the correlation between both, the more adequated the χ2 will be as a measure of convergence (Archibugi and Pianta, 1992: chapter 8; Pianta and Meliciani, 1996). The correlation index for the UE-15 group was 0,7835, which confirm the χ2 robustness. [↑](#footnote-ref-5)
5. This paper uses the Patel and Pavitt´s methodology to classify competences from RTA values and the relative innovative effort over a “medium value” calculated as 1/n, with n=120 technical fields. [↑](#footnote-ref-6)