ON THE RELATIONS BETWEEN TECHNOLOGICAL OPPORTUNITY, SPECIALIZATION AND GROWTH

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Resumo.

Este trabalho tem o objetivo de discutir o papel da especialização tecnológica no crescimento econômico. A literatura aponta que há suficientes razões teóricas e evidência empírica para associar positivamente a especialização comercial e produtiva em produtos de alta tecnologia com crescimento. Há também razões para associar a especialização tecnológica em tecnologias com elevada oportunidade tecnológica (corretas especializações) com maiores ritmos de progresso técnico, o que não é sempre confirmado pela evidência empírica. A partir de uma base de dados com informações para 38 países entre 1985 e 2005, este trabalho confirma que não há evidência para confirmar a irreversibilidade da mudança tecnológica a partir de uma dada especialização tecnológica, comprovando a contribuição de "corretas especializações" ao crescimento a partir de uma visão dinâmica da oportunidade tecnológica.

Abstract

This paper aims to discuss the role of technological specialization in economic growth. Economic literature has stressed that there are theoretical reasons and empirical results to associate trade specialization in high-tech products with growth. There are also theoretical reasons to associate technological specialization in dynamic technological opportunity fields ('correct specialization') with rhythms of technological advance, which is not usually confirmed by empirical studies. Using data from 1985 to 2005 for 38 countries, this paper shows that there is no evidence to confirm that a certain technological specialization implies technical change irreversibility. The paper also confirms the contribution of 'correct technological' specialization to growth.

Palavras-chave; especialização tecnológica, especialização industrial, oportunidade tecnológica, crescimento, mudança estrutural.

Keywords; technological specialization, industrial specialization, technological opportunity, growth.

Área ANPEC; Crescimento, Desenvolvimento Econômico e Instituições

Classificação JEL; O30, O50, O33

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Introduction

Economic literature has recognized the central role played by technical change as a determinant of economic growth. In neoclassical models, technical change shifts production function outward increasing labor and capital productivity. In Schumpeterian models, technical change appears as the central transformation force. In demand-led models, technical change pushes economic growth through increases in competitiveness that promote the growth of exports in competitive and highly income-elastic goods (Meliciani, 2002; Montobbio and Rampa, 2005). Conventional wisdom has also posed that in order for these forces to be magnified, countries must be 'correctly' specialized, that is, their production should be in industries of high potential for productivity growth, their exports should be concentrated in goods with high income elasticity and their technological profiles in technical fields with the highest technological opportunities (TO) that may provide positive knowledge spillovers through the building of technological bases and capabilities to advance in future technological developments. Under all these approaches, there is still the idea of some degree of irreversibility (hysteresis in technologies and exports). This means that initial specializations reproduce themselves, determining future profiles of specialization, technological dynamism and rates of growth.

Nevertheless, empirical evidence on this issue is quite controversial. Although the 'correct specialization' seems positive and significantly associated with growth, the effects don't seem to be as strong as literature expected. Furthermore, literature has not yet gathered enough empirical evidence to state the superiority of a specific technological specialization over others in terms of ensuring advances in technological development or escaping from long run technological constraints. However, this kind of conclusion tends to be important, especially in developing countries.

The purpose of this paper is to test for a set of 38 countries the association between their technological specialization and their technological evolution and their impact on per capita GDP growth from the mid-eighties to the first decade of this century. Therefore, the paper attempts to define 'good technological specialization' based on an analysis of the dynamic nature of technical change and on the assessment of TO across technical fields. Furthermore, the paper tests for the stability of technologies in different TO levels and the role of TO in determining per capita GDP growth.

Apart from this introduction, the paper has three sections. The first section discusses the theoretical reasons that drive the association between 'correct' specialization and growth and the main empirical results founded in literature. The second section analyses the role of 'correct technological specialization' in the path of technological development by countries from a dynamic interpretation of technological opportunity. The third section elaborates a model to test the influence of technological specialization on growth. Finally, the paper presents the main concluding remarks.

1. On the 'quality' of technological specialization.

There is an extended idea in the literature that technological specialization matters in long term growth due to its potential effects on its: i) commercial specialization; ii) industrial productivity distribution; and iii) capacity to move towards technological classes with superior technological opportunity.

The relation between technological specialization and commercial specialization relies on the hypothesis that exports growth and changes in the distribution of sectoral exports are mainly determined by *competitiveness* of products and sectors. Competitiveness is, at least in part, determined by technological efforts on *specific* technical fields with high technological opportunity, that is, technical fields that have the highest possibilities to be exploited in terms of market and knowledge (Fagerberg, 1988 and 2007; Amendola et al, 1998; Lall, 2000; Montobbio and Rampa, 2005). As these technologies are usually related to new techno-scientific paradigms, sectors (products) that incorporate them are seen as knowledge intensive[2], characterized by a greater capacity to generate a relative higher value added and a more dynamic demand (for instance, higher income elasticity). The specialization in this kind of products and technologies avoids competition by wages and prevents shifts in technology and market paths (Huang and Miozzo, 2004). As a consequence, when a country specializes in this kind of technologies, it acquires a 'good technological specialization' and it is in conditions to increase its exports by changing the composition of its export structure towards more dynamic markets and products and establishing a path to long term economic growth. Different theoretical approaches – such as neoclassical (Grossman and Helpman, 1991) postkeynesian (Vespargen, 1993) and neoshumpeterian (Fagerberg, 2007; Meliciani, 2002) – converge to this proposition.

For developing countries these predictions remain valid, but have some specificities (Montobbio and Rampa, 2005; Huang and Miozzo, 2004). These countries have lower possibilities to *exploit* new technological paradigms than industrialized countries because they have tighter constraints to identify, explore and apply the set of possibilities that these technologies offer due to their limited scientific and technological base (infrastructures, low industrial R&D efforts, scarce of human qualification, etc.) (Alcorta and Peres, 1998). The alternative for developing countries is to *catch-up*. As literature recognizes, catching-up needs the accumulation of technological capabilities[3] that generate absorptive capacity to capture knowledge generated by leaders (Bell and Pavitt, 1997). Thus, even in developing countries, 'good technological specialization' may play an important role in ensuring long term growth, because technological activity in 'good technologies' is needed to achieve catching up rhythms that ensure the development of 'good markets', in the sense that they are markets that guarantee higher levels of competitiveness and growth.

The relation between technological specialization and productivity responds to the 'Ricardian view' of productive specialization, that is, specialization matters because productivity growth rates are unevenly distributed across industries. Specialization in sectors with higher opportunities for productivity growth allows a faster rate of economic growth due to three effects: their own impulse, spillover effects on other industries and differentials in income elasticity with respect to other activities (Jungmittag, 2004). The direct and strong association that scholars have established between technologies with high technological opportunity and sectors with high potential for productivity growth suggests that specialization in 'good technologies' ensure the specialization in 'good activities' (usually R&D intensive) and conduct to long term growth.

The third relationship is based on the idea that previous technological specialization determines the possibilities to move towards technological classes with superior technological opportunity. According to this view, future 'good specialization' requires past 'good specialization' (Brusoni and Geuna, 2003). This should be a result of persistence of technological patterns of specialization associated with path dependence in cumulative processes like R&D and learning. Specialization in technologies with high technological opportunities means greater potential for application of new scientific and generic knowledge in other activities (pervasiveness) and for developing further learning processes (Lall, 2000; Huang and Miozzo, 2004). Specialization in mature technologies (low opportunity) limits the building of absorptive capacity that allows the absorption of new knowledge released from new technological paradigms and, as a consequence, hinders movements towards 'correct' technical fields (high opportunity). This effect may be even more devastating in developing countries

[2] In fact, Montobbio and Rampa (2005) draw the hypothesis that technological variables have more relevance for competitiveness in sectors with higher technological intensity, that is, in knowledge intensive sectors. Huang and Miozzo (2004) use the country's specialization in specialized suppliers and science based as a proxy for high technology products specialization.

[3] The accumulation of technological capabilities is a result of the undertaking of a large set of activities such as imitative or adaptative R&D efforts, learning by doing or the human capital qualification.

that have not yet developed the proper institutional framework and public policies to stimulate the 'social process of learning' that enables the reversion of such perverse trend (Vertova, 2001).

Empirical evidence on these propositions is controversial. Analyzing changes in technological specialization in industrialized countries over 100 years (from pre WW1 until nineties) and considering the main techno-scientific paradigms in the twentieth century, Vertova (2001) concludes that "most countries did not historically have the capability to specialize in the high technological opportunities (fast growing technologies). It seems that "countries become locked in inferior technological paths and are not able to move away". Jungmittag (2004) concluded that there is little empirical evidence that technological Smithian specialisation is conducive to economic growth in EU countries, but Ricardian specialization in R&D-intensive industries (especially in leading-edge industries) contributed significantly to economic growth between the seventies and the nineties. His empirical results drove him to conclude that the process of structural change towards R&D-intensive industries should be supported by public policy.

Alternatively, Laursen, (1999), using UPSTO and working with OECD countries from the sixties to the eighties, found that most catching up countries (Japan, Finland, Ireland, Spain, Austria, Italy and Turkey) registered high levels of technology growth even if they had appeared to have been 'wrongly' specialized in the sixties. Malerba e Montobbio (2004) found that, with rare exceptions, the technology effect was the most important component explaining patent share growth between the periods 1978-1982 and 1994-1998 for sixteen OECD countries; that is, the effect that measures the part of growth due to technological dynamism and not due to technological specialization. They even left aside from any explanation the cases where 'wrong specializations' lead to high technological dynamism and vice-versa. Montobbio and Rampa (2005) concluded in their study that developing countries tended to concentrate their technological activity in stagnant technologies and this international trend partly offsets generalized national improvements in terms of patent shares. This negative impact should have effects in "the inherited patterns of technological specialization the difficulties of shifting out from activities offering poor technological opportunities and of entering dynamic sectors".

On the test of the virtuous circle between 'good' technological and commercial specialization and growth, Laursen (1999) concludes that initial good technological specialization does not mean fast growing exports. Nevertheless, there is a positive relationship between the fast growing rates of exports and the ability to move to fields with higher levels of technological opportunity. On the contrary, Huang and Miozzo (2004), comparing East Asian and Latin American patterns of specialization, showed that Asian specialization in electronics, computers and communications are associated with a shift of trade specialization from the supply-dominated and scale-intensive sectors to specialized supplier or science-based sectors, which "reflects the transformation of East Asia's export structure with increasing technological intensity and autonomy". In opposition, Latin American countries maintained their specialization in drugs and medical products as well as agriculture, husbandry and food sector (primary sectors) that remained unchanged for 30–40 years. This technological specialization is associated with an increasing trade specialization in supply-dominated and/or scale-intensives sectors.

Finally, using patent data from UPSTO from the sixties to the mid-nineties for 18 OECD countries, Meliciani's (2002) concludes that specialization in fast-growing technologies is positively associated with the rate of growth of exports and helps GDP growth. But no significant correlations are found between specialization in fast growing technologies and rate of growth of GDP or exports.

One may observe that some countries move to dynamic technologies and industries (mainly developing countries), while others remain in their unfavorable specialization. There is a consensus that public policies play a central role in the strengthening of the country's technical base, fostering catching-up (Miozzo, 2002; Alcorta and Peres, 1998). At the same time, changes in technological profiles do not arise spontaneously. Literature has identified that there is a path to build technological specialization. Miozzo (2002) shows that machinery technologies are central to the development of the electronic and computer industries and that advances in electronics and information technologies need the development of strong competences in mechanical, electromechanical and precision engineering technologies. So, the development of a solid technical base is not a sufficient condition for catching-up, but it should be accompanied by the development of competences in technical fields that sustain future developments.

Simultaneously, it seems difficult to empirically observe a clear theoretical relationship between 'good technological specialization', 'good commercial specialization' and growth of exports and production. There are some possible explanations for that. First, most of these studies use RTA indicator (Revealed Technological Advantage) from patent counts as a relative measure of specialization of a reference area. Nevertheless, neither patents measure national capabilities in Archibugi and Coco's (2005) sense nor does RTA capture the 'technological potential' of a country, that is, RTA indicators deliver very little information about the strength of a national technical base (Meliciani, 2002). And agreeing with Meliciani, levels of technological development also matter in the evaluation of different growth opportunities. This explains why delayed countries can register above-average rates of growth, even with unfavorable initial specializations.

Second, sometimes literature works with 'preconceived' or 'narrow' ideas on what are 'good technologies', that is, they have a preconceived idea about what technical fields have high technological opportunities. These ideas are generally related to telecommunication and electronics techno-scientific paradigms. But the truth is that technological opportunity is a dynamic concept and 'opportunities' that a technology offers are constantly changing along the path of technological advances. This is caused by the natural evolution of technological trajectories (the extent to which initial paradigms are exploited and applied) and the way this evolution permeates other technologies, spreading the whole of possibilities from an initial technological paradigm over other fields of knowledge.

In third place, empirical evidence is based on a linear correspondence between patent classifications and trade products or industrial classifications, which may be misleading. Neither do products contain unique technologies nor can technologies be applied to only one product (or set of products) that belong(s) to a sole industry. To be specialized in one technology should be interpreted as a competitive advantage in a set of products and industries that use that technology. In this sense, taking of advantages from technological opportunities is closely related to the way countries introduce or adapt the possibilities from paradigms (potentially widely pervasive to different industries) to their specific productive structures and markets. For example, electronic components can be used by China to produce toys, by Korea to produce audiovisual equipments for cars or by Brazil to produce sensors in deep water extracting petroleum, and to do that, these countries does not necessarily have to be specialized in electronic components.

As time goes by, all these effects are strengthened and consolidated in a country's technological base and patterns of technological specialization cannot be understood as exogenous anymore. The technological profiles of a country are the result from the interaction and co-evolution of all the economic structures (productive, technological and commercial), whose effects in national competitiveness cannot be evaluated only in terms of specialization in a few specific industries.

2. Qualifying technological specialization as a constraint for technological development.

This work uses patent data filed in the European Patent Office (EPO) between 1985 and 2008 to measure technological specialization. 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. Firstly, patents reveal distributions of competences across technical fields but not distributions of capabilities. 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 there are complementarities between all three categories, the sole use of patents underestimates the set of aspects that transform a competence into a capability (Archibugi and Coco's 2005) 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). On the other hand, a country may have strong competences and capabilities in development weakly supported by basic knowledge (*ibidem*). And finally, 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 for international comparisons when compared with UPSTO patent database (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 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) all patents were included independently of whom the applicant was. 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).

Data was aggregated in 29 technological fields according to the Fraunhofer Insitute Classification as published in Mancusi (2003). Telecommunications and Audiovisual Technologies were aggregated in the same technical field. The technological specialization was calculated for 38 countries (see Table 2 for a list of the countries).

The most usual way to identify specialization in different technological fields with elevated technological opportunities is through initial share of patents or initial RTA in fast growing patent technical fields (Huang and Miozzo, 2004; Meliciani 2002; Montobbio and Rampa, 2005). Table 1 presents the most fast-growing technologies by periods between the mid-sixties to 2000-2005 using and comparing data generated by us and data generated by Huang and Miozzo (2004). Though data sources and classification are different (we use EPO and Huang and Miozzo use USPTO) the examination of these results may provide some useful insights:

(i) The evolution from drugs paradigm towards information and communication (electronic) paradigm as well as new materials (semiconductors) seems a regular pattern from the seventies to the eighties and nineties.

(ii) The last period in Huang and Miozzo (2004)'s work is quite compatible with our first period. In this time, audiovisual, telecommunications and information technologies grow explosively, with a second wave of strong growth relative to chemical and biotechnological paradigm (organic chemistry, oil and basic material chemistry, biotechnology or medical devices).

(iii) In the second half of nineties, both paradigms keep growing strongly but some new fields appear like engines and pumps, transport and control and measurement technologies as dynamic as the previous ones, which probably is a consequence of the pervasive effect of the electronic paradigm.

(iv) The last period shows lower rates of growth of patent share in leading technologies when compared to other periods, which may indicate a more uniform rate of growth across sectors.

(v) Technologies usually considered as ‘low opportunity’ showed very strong growth, which is probably the effect of the expansive wave of technological advance in electronic and biomedical paradigms. Those are the cases of consumer goods, food and agriculture, transport, pharmaceutical and cosmetics, material processing or mechanical elements.

(vi) This picture may conduct one to consider that leadership across technologies has showed a quite strong turnover.

Table 1. Dynamic TO technologies by period: Rank according to rate of growth of the patent share for fast-growing technological classes.

RANK	1986-1990 1991-1995		1991-1995 1996-2000		1996-2000 2000-2005	
1	Biotechnology	34,61	Information technology	62,61	Medical technology	9,48
2	Audio-visual tecnologies, telecomunications	29,45	Audio-visual tecnologies, telecomunications	41,11	Oil and basic material chemistry	8,85
3	Information technology	27,98	Pharmaceuticals and cosmetics	33,91	Consumer goods	4,30
4	Organic chemistry	14,09	Engines, pumps	33,38	Pharmaceuticals and cosmetics	4,20
5	Medical technology	12,26	Biotechnology	26,19	Transport	2,57
6	Optics	11,60	Medical technology	19,54	Audio-visual tecnologies, telecomunications	2,09
7	Electronic deivices, electrical engineering	6,49	Transport	16,74	Control and measurement technology	1,81
8	Semiconductors	5,27	Control and measurement technology	2,38	Engines, pumps	1,60
9	Oil and basic material chemistry	3,06	Semiconductors	0,47	Food and agriculture	1,24
10					Materials processing	0,59
11					Mechanical elements	0,41
	Huang and Miozzo (2004) results*					
RANK	1965–1969 1975–1979		1975–1979 1985–1989		1985–1989 1995–1999	
1	Drugs	3,06	Computer peripherals	2,91	Biotechnology	4,82
2	Computer peripherals	2,79	Computer hardware and software	2,66	Computer hardware and software	3,72
3	Biotechnology	2,16	Surgery and medical instruments	2,09	Semiconductor devices	3,70
4	Surgery and medical instruments	1,85	Biotechnology	2,05	Computer peripherals	3,36
5	Miscellaneous drugs and medical	1,82	Information storage	2,01	Information storage	2,59

(*); Huang and Miozzo (2004) source was NBER US Patent Citation Data File
Source: Espace Bulletin. EPO 1978-2008.

In order to analyze countries’ specializations and to address some hypotheses previously formulated, we have calculated the Revealed Technological Advantage index (RTA_{hj}) in fast-growing technologies, represented by $\frac{p_{hj}}{p_{hW}}$ where p_{hj} is the j-country share or patents in fast growing technical fields and p_{hw} is the share of patents in the same technical field for the whole world. The results are reported in Table 2. One can observe that technological specialization in high technological opportunities fields are not clearly related to the technological leadership. The high turnover across technologies in the leadership seems to affect also the relative position of countries. Countries may become specialized in some technologies through different productive specializations. This result is compatible with the idea that countries take advantages of the new technological paradigms according to their potentialities in terms of productive and market specificities.

Second, specialization in technologies that have shown the highest dynamicity in the whole period (1986-1990 to 2001-2005 column 4 in table 2) does not reflect how countries take advantages of technological opportunity through time. For example, Japan, United States, Mexico or Singapore look ‘well specialized’ in column 4, but they were not ‘correctly’ specialized in the 1996-2000 period given the path of opportunity that technologies followed between 1996-2000 and 2000-2005. On the other hand, United Kingdom, Sweden, Finland, Norway and Hong-Kong look ‘badly specialized’ for the whole period, but they follow a path of ‘good specialization’ for the last two periods. Only in a few cases the specialization for the whole period expresses good position maintained for in each and every period (South Korea and Israel). On the other hand, the specialization for the whole period tends to reflect correctly the situation mantained for each period when it was a 'bad specialization'. These are the cases of Canada, Germany, Austria, Belgium, Italy, Luxemburg, Denmark, Spain, Portugal, Switzerland, New Zeland and South Africa.

Table 2. RTA specialization in fast-growing technologies by country and by period.

		9195/8690 (1)	9600/9195 (2)	0105/9600 (3)	0105/8690 (4)			9195/8690 (1)	9600/9195 (2)	0105/9600 (3)	0105/8690 (4)
Leaders	Japan	1,43	1,08	0,88	1,21	European non EU	Iceland	0,73	1,53	1,26	1,11
	United States	1,24	1,17	0,93	1,11		Switzerland	0,82	0,76	0,92	0,65
	Canada	0,9	0,92	0,98	0,83		Norway	0,59	0,96	1,04	0,77
EU-15	Germany	0,8	0,8	0,98	0,86		Hungary	1,16	0,89	0,95	0,85
	France	0,84	1,04	1,03	1,02		Poland	1,05	0,92	0,94	0,79
	United Kingdom	0,91	1,08	1,02	0,97		Russia	0,75	0,92	0,92	0,71
	Austria	0,57	0,76	0,89	0,76	Latin Americans	Argentina	0,83	1,15	1,35	1,18
	Belgium	0,72	0,59	0,66	0,61		Brazil	0,93	0,84	0,93	0,97
	Italy	0,7	0,79	0,94	0,89		Chile	0,13	1,11	0,91	0,57
	Luxembourg	0,21	0,58	0,96	0,78		Mexico	1,15	0,97	0,77	1,31
	Netherlands	1,1	0,9	0,91	1,06	Asian	China	0,99	0,95	0,9	0,95
	Sweden	0,71	1,08	1,14	0,89		Hong-Kong	1,49	0,73	1,22	1,42
	Finland	0,59	1,08	1,23	0,69		India	1,62	0,82	0,78	0,75
	Denmark	0,8	0,95	0,96	0,9		South Korea	1,44	1,27	1,08	1,33
	Spain	0,73	0,9	0,97	0,92		Singapore	1,29	1,01	0,85	1,31
	Greece	0,8	0,99	1,13	1,23		Taiwan	0,79	0,93	1,02	1,06
	Ireland	0,92	1,19	1,07	1,03	Others	Australia	0,82	1,09	0,92	0,95
	Portugal	0,7	0,95	0,91	0,9		New Zeeland	0,52	0,81	0,99	0,64
							Israel	1,09	1,41	1,15	1,04
							South Africa	0,41	0,78	0,87	0,57

Source: Espace Bulletin. EPO 1978-2008 and own elaboration.

To associate the quality of technological specialization with technological dynamism and with the ability to move to more dynamic TO fields, we turn to shift-share analysis. Shift-share allows to decompose the growth of a country´s patent share by components in the following way. Denoting p_j as the share of patents of the j-country in the world; p_{ij} as the share of patents of the j-country in the i-technical field over the same technical field in the world; o_i, the share of patents of the i-technical field in the world; s_{ij} 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;

$$\dot{p}_j = \sum_i s_{ij}^{t-1}\dot{p}_{ij} + \sum_i s_{ij}^{t-1}\dot{o}_{ij} + \sum_i s_{ij}^{t-1}\dot{p}_{ij}\dot{o}_{ij}$$

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.

Table 3. Decomposition of the Growth of Patent Shares in Technology, Structural and Adaptation Effects.

		1986-1990 1991-1995				1991-1995 1996-2000				1996-2000 2000-2005			
		TEC.E	STRUC.E.	ADAP.E.	TOT. E.	TEC.E	STRUC.E.	ADAP.E.	TOT. E.	TEC.E	STRUC.E.	ADAP.E.	TOT. E.
Leaders	Japan	-9.42	5.09	-1.89	-6.22	-7.24	1.93	-4.03	-9.34	8.03	-0.68	0.13	7.49
	United States	-0.19	2.97	-0.80	1.98	-2.53	3.19	-3.22	-2.56	-2.34	-0.16	0.33	-2.16
	Canadá	-29.18	-0.99	-0.08	-30.25	103.83	-2.00	1.90	103.72	10.43	-0.40	0.33	10.36
EU-15	Germany	-13.94	-2.60	-1.49	-18.03	9.45	-4.29	-1.02	4.14	-2.51	-0.08	-0.04	-2.62
	France	-8.66	-2.07	-1.11	-11.84	-9.21	1.34	-3.02	-10.89	-4.10	0.07	0.06	-3.97
	United Kingdom	-21.69	-0.53	-1.05	-23.26	-4.76	1.42	-2.61	-5.95	-5.33	-0.07	0.16	-5.24
	Austria	-7.88	-5.61	0.07	-13.42	3.54	-3.90	-3.29	-3.65	12.35	-0.21	-0.07	12.06
	Belguium	12.36	-2.90	-0.73	8.72	27.79	-9.11	-5.36	13.32	-3.30	-1.38	0.49	-4.20
	Italy	-1.07	-2.87	-1.29	-5.24	2.13	-3.01	-3.89	-4.78	3.53	0.26	0.05	3.84
	Luxembourg	7.21	-9.52	-1.78	-4.08	54.28	-10.61	-3.53	40.14	21.97	-0.56	0.27	21.69
	Neetherlands	-15.84	0.36	-1.94	-17.42	13.47	-0.03	-1.81	11.62	15.58	-0.44	-0.06	15.07
	Sweden	-1.32	-3.73	0.43	-4.62	20.60	1.93	-0.08	22.45	-11.54	0.64	-0.05	-10.95
	Finland	50.49	-3.94	4.25	50.80	27.53	3.23	3.36	34.11	0.98	0.37	-0.05	1.29
	Denmark	85.63	-1.64	-6.58	77.41	2.52	-0.84	-1.56	0.13	12.79	-0.40	0.41	12.80
	Spain	47.01	-2.35	-3.84	40.82	28.59	-0.54	-6.90	21.15	34.42	0.16	-0.06	34.52
	Greece	37.60	-3.30	-4.02	30.28	19.82	-0.40	-1.37	18.05	23.52	0.81	-0.33	24.00
	Ireland	12.07	0.47	-1.77	10.77	47.01	7.02	-1.51	52.52	11.71	0.64	0.54	12.89
	Portugal	50.91	-5.00	-3.16	42.75	40.54	1.83	-9.12	33.25	46.47	0.02	0.13	46.63
European non EU	Iceland	54.88	-0.33	4.53	59.08	40.41	12.14	1.47	54.02	25.26	0.88	-1.68	24.46
	Switzerland	-14.82	-2.15	-0.67	-17.65	0.20	-5.99	-1.41	-7.20	0.23	-0.04	0.25	0.45
	Norway	8.65	-3.57	-2.02	3.07	25.35	-1.43	-3.27	20.65	-2.17	0.10	-0.11	-2.18
	Hungary	-56.03	-0.46	0.97	-55.53	-0.76	-2.22	-2.44	-5.41	39.36	0.18	0.27	39.81
	Poland	-23.63	-0.89	-0.04	-24.57	10.53	-5.07	-0.81	4.65	119.66	-0.17	-0.32	119.17
	Russia	14.35	-5.59	-0.63	8.13	31.78	-4.36	-3.31	24.11	-4.00	-0.41	-0.13	-4.54
Latin Americans	Argentina	67.96	-1.24	-2.87	63.84	45.40	3.56	2.22	51.18	5.39	1.87	-1.01	6.25
	Brasil	55.60	-1.86	-3.84	49.89	47.39	-2.50	-8.02	36.87	36.09	-0.16	0.09	36.01
	Chile	-4.99	-11.65	4.78	-11.86	57.06	1.77	-15.29	43.54	49.05	-0.73	-1.02	47.30
	Mexico	24.70	4.61	-6.22	23.10	71.22	-0.11	-14.44	56.67	59.60	-1.10	1.53	60.03
Asian	China	-3.08	-0.23	-0.45	-3.76	159.42	-0.16	-7.79	151.47	293.01	-0.53	1.78	294.26
	Hong-Kong	7.27	2.91	-1.69	8.49	-31.34	2.90	-1.53	-29.97	0.65	0.75	-0.41	0.98
	India	3.03	6.22	-3.69	5.57	145.29	-4.10	-4.52	136.68	207.21	-0.30	-0.76	206.15
	South Korea	445.11	4.67	37.41	487.20	86.58	9.27	-1.45	94.40	176.56	-0.11	1.44	177.89
	Singapure	137.34	2.45	10.86	150.66	72.01	6.73	7.93	86.67	130.71	-0.81	0.07	129.97
	Taiwan	27.03	-1.93	1.13	26.24	2.88	2.83	-2.10	3.62	103.02	0.35	0.22	103.58
Others	Australia	-11.65	-1.81	0.18	-13.28	9.76	1.33	-3.15	7.93	22.24	-0.21	0.09	22.11
	New Zeland	6.80	-7.43	3.10	2.47	37.48	-1.51	-0.28	35.69	37.33	-0.05	0.38	37.66
	Israel	34.23	1.11	2.77	38.11	33.61	9.42	1.33	44.36	23.78	1.01	0.57	25.36
	South Africa	-16.99	-7.76	1.98	-22.77	4.70	-4.51	-2.18	-1.99	-7.15	-0.08	-0.33	-7.55

Source; EPO Space Bulletin and own elaboration.

Table 3 presents a shift-share of the results by country and groups of countries. The negative sign of the technological effect is the main explanation of the negative total effect in the case of non-European leaders, especially from the mid nineties. The positive sign of the structural effect offsets the negative sign of the technological effect, from the mid eighties to the mid nineties. This means that their specialization reduced their patent share loss during this period when they showed a relative technological stagnation. Nevertheless, this initial favorable specialization position changed in the mid nineties when only technological dynamism allowed Japan and Canada to register positive growth of patent shares.

For European Leaders (Germany, France and United Kingdom), the loss of patent shares was mainly due the technological effect, though all three effects appear with negative sign. For European medium technology level countries, the same observation can be made. In general, indenpendently of the sign of the total effect, the technological effect is eventually the main explanatory variable, especially in the period between mid nineties and 2000-2005. Luxembourg, Italy and Sweden seem to be exceptions, where the dimension of the structural component was high enough to determine the falloff of their patent shares in the first period (86-90; 91-95). This is also the case of Austria during the nineties, where the three effects have the same importance but with opposite signals. European Delayers (Spain, Greece, Portugal and Ireland) registered high growth rates of their patent shares mainly due to the technological effect, which compensated an initial unfavorable position, and the adaptation effect, which conducted the countries to 'incorrect specialization'.

In the group of non-EU European countries, the technological effect is also the main explanatory component for their patent share, in the cases of both positive and negative growth. Iceland and Norway followed a rising tendency of their patent shares. There is an exception for Norway in the last period when it lost patent share. Switzerland was the case in which the structural effect had a relative importance to explain its patent share fall along the nineties. Eastern countries show the same trend. Technological effect is the most important explanatory component for the fall and rise of Hungary and Poland patent shares, as well as the rise and fall or Russia's patent share along the three periods.

Latin-American countries (Argentina, Brazil, Chile and Mexico) registered important positive patent share growth from mid eighties until recent years and the main explanatory component is the technological effect that counteracted the negative contribution of incorrect specialization and the negative effect of the movement towards stagnant technical fields. The only exception was observed in Chile between mid nineties and mid eighties when the loss of patent share was explained by a strong influence of a very unfavorable specialization and movements towards stagnant technologies that offset the dynamism of the technological effect.

Asian countries follow the same trend with even with higher growth rates, like the cases of South Korea and Singapore between 86-90 and 91-95 periods; India and China between 91-95 and 96-00 periods; and all four between 96-00 and 00-05. For all periods and countries it can be observed that the unique component that drove to those results was the technological share effect. The structural effect remains residual and only the adaptation effect acquires some importance, like in the cases of South Korea and Singapore between 86-90 and 91-95. The structural effect only plays a major role for India between 86-90 and 91-95, where also the negative adaptation effect annulled the small but positive technological effect.

In the last group of countries, Australia, New Zeland and Israel moderately increased their patent shares along the three decades. The main driver of this trend is again the technological effect in all cases and periods. It should be stressed however that in New Zealand from 86-90 to 91-95 periods, the negative sign of the structural effect compensated the dynamism of the technological effect. South Africa had constant falls in its patent shares that were mainly caused by a reduction of its technological dynamism.

In resume, the data does not support the hypothesis that a good initial specialization of a country is associated with growth of its patent share. Only exceptionally, and mainly in the first period of analysis (between 86-90 and 91-95) initial specialization determined the path of growth, be it positive or negative. The contribution of technological effect is the driving force in catching-up countries, that is, the effect of initial good specializations or movements towards dynamic TO fields is even less important under catch-up processes.

Another way to test the role of specialization in technological dynamism is testing for a positive correlation between $RTA_{hj}^{t1,\ t2,\ t3}$, RTA_{hj}^{T} or the structural technology effect and the technology adaptation effect. If specialization in dynamic TO sectors facilitates the entry in new emerging technologies, this correlation would be positive and significant. The results show that the hypothesis does not hold (table 4). None of the three indicators has a positive and significant correlation with the adaptation effect. On the contrary, the adaptation effect is positively and significantly correlated with the technological effect, maybe stressing the pervasive role of general technological effort.

Table 4.- Pearson correlations between shift-share components and specialization in dynamic TO technologies.

	Total Effect	Technologial Effect	Structural Effect	Adaptation Effect	$RTA\text{-}DTO_t$
Technological Effect	0,9960				
P-value	*(0,0000)*				
Structural Efect	0,2125	0,1577			
P-value	*(0,0347)*	*(0,1191)*			
Adaptation Effect	0,5647	0,5069	0,0791		
P-value	*(0,0000)*	*(0,0000)*	*(0,4365)*		
$\mathbf{RTA_{hj}^{t1,\ t2,\ t3}}$	0,1911	0,1422	0,8565	0,0955	
P-value	*(0,0582)*	*(0,1602)*	*(0,0000)*	*(0,3470)*	
$\mathbf{RTA_{hj}^{T}}$	0,2106	0,1845	0,5134	0,0844	0,4825
P-value	*(0,0364)*	*(0,0676)*	*(0,0000)*	*(0,4063)*	*0,0000*

$RTA_{hj}^{t1,\ t2,\ t3}$ is the RTA at the beginning of each period in technologies with dynamic TO by period; RTA_{hj}^{T} is the RTA with dynamic TO for the whole period (1986-1990 and 2001-2005).
Source: Espace Bulletin. EPO 1978-2008 and own elaboration.

Though significant at the 10% level, the correlation between the three specialization variables ($RTA_{hj}^{t1,\ t2,\ t3}$, RTA_{hj}^{T} and the Structural effect) do not always correlate significantly with the technology and the total effects. Furthermore, the correlation is far from strong. This result breaks in some way with the idea that technical specialization has an irreversible character and that 'wrong technological specialization' conditions future developments in anyway. The taking of the advantages that technological paradigms provide is more probable to occur if the country develops significant technological activity. And this activity does not necessarily have to be focused on the 'good technologies', but in technologies that permits to combine the advances in knowledge to their own specificities in terms of production and markets.

3. Testing the effect of technological specialization on growth

One way to analyze the role of technological specialization constraints is through the elaboration of growth models that attempt to capture the influence of technological specialization on per capita GDP growth. Two previous papers have pursued this trend. On the one side, Jungmittag (2004) departs from a Solow-type model in which where GDP growth is determined by the rate of growth of exogenous technical progress, the rate of growth of the capital stock, the rate of growth of the population, the rate of growth of efficiency due to the rate of growth of R&D activities and the rate of growth due to technological specialization. The rate of growth of exogenous technical progress is determined by two components. On the one hand, it is determined by the rate of absorption of external knowledge and, on the other hand, by country specific factor endowment characteristics. The rate of absorption of external knowledge is divided in two main components. First, it should be positively correlated with the technological gap the country has in relation with the reference country, which implies a negative relation with its previous per capita GDP that represents the country's level of technology. Second, the rate of absorption of external knowledge is related to the level of technological effort undertaken by the country which is represented by the rate of growth of the technological stock (patent stock) and the relative technological specialization.

The point of Jungmittag (2004) model is to test directly the effect of technological activity and its specialization characteristics on per capita GDP. In this sense, it takes a production function view of innovation and tries to see how technical progress affects the production function and therefore per capita GDP.

Meliciani's (2002) model has a different perspective and does not tackle the direct effect of technology on the production function but sees that GDP is indirectly affected by technical change through the enhancement of competitiveness and therefore its effect on the balance of payment. It departs from a demand-led balance of payment constrained model where a simultaneous equation estimation model[4] is used. In this conception, GDP growth is constrained by the necessary balance of payment equilibrium. The balance of payment equilibrium equation departs from one import and one export equations. The imports and exports levels are determined by a parametric relation with domestic and world demand, respectively. These relations are determined by two main components: (i) relative price of exports (domestic and world); and (ii) relative technological competitiveness. The relative technological competitiveness is determined by disembodied innovation, embodied innovation (capital stock) and the quality of specialization. The equilibrium between the two balance of payment equations determines the level of income.

We follow Fagerberg et al. (2007) that tries to capture both transmission channels. On the one hand, GDP is a function of knowledge, $Y = f(T, C)$, where *Y* is GDP, *T*, technological knowledge and C, the capability for exploiting the benefits of knowledge. *T*, on the other hand, is determined by externally produced knowledge and knowledge produced in its own country. As in Jungmittag (2004), the contribution from externally produced knowledge is an increasing function of the technological distance from the technological leader and the analyzed country. Knowledge produced in the country is a function of two sets of factors. On the one hand, knowledge produced is a function of the technological effort undertaken in the country, on the other hand, it is a function of the technological location of this effort, that is, its technological specialization. Therefore, $T = h(N, D)$, where *N* is nationally produced knowledge and *D* is internationally produced knowledge, whereas D is a negative function of the ratio T_i/T_l, where "i" stands for country *i* and *l* for leader country.

In order to account for the role played by the balance of payment, Fagerberg includes a restriction of equality between the country's imports and exports where $X = x(T, C, P, W)$, in what *X* stands for exports, *P*, for price competitiveness, and, *W*, for world's demand. On the other hand, the import function would be defined as $M = m(1/T, 1/C, 1/P, Y)$.

As in Fagerberg et al. (2007) we test for a reduced form of these equations where:

$$g_i = \propto + \beta_1 Y_{t-1} + \beta_2 n_i + \beta_3 c_i + \beta_4 p_i + \beta_5 w_i + \mu_i \qquad (1)$$

Where Y stands for per capita GDP, representing the catching-up potential, that is, the possibility to absorb new knowledge, *n* stands for growth of domestically produced income, *c* for growth of domestic capability, *p* for growth of price advantage in international market and *w* for the growth of world demand for domestic products.

[4] Inspired in Fagerberg (1988).

In contrast with Fagerberg et al. (2007), we let the growth of domestically produced knowledge be a function of the domestic technological specialization. Therefore, we decompose the n term in one component related to the country's increased overall effort and one component associated with technological opportunity enjoyed by the country's previous technological specialization (RTA indicator) or two components associated the structural effect (technological opportunity) and adaptation effect. Therefore, we test the following two equations:

$$g_{it} = \propto + \beta_1 y_{it-1} + \beta_2 tot_{ii} + \beta_3 RTA_{it-1} + \beta_4 dcap_{it} + \beta_5 dulc_{it} + \beta_6 lhte_{it-1} + \mu_i \quad (2)$$

Where, *y* stands for per capita GDP in the base year, *tot*, for the rate of growth of the country's share of patents, RTA, the revealed technological advantage previously defined, *dcap*, the rate of growth of the country's capability, represented by the share of the population over 25 years old which completed at least the upper secondary school, *dulc* is the rate of change in the unit cost of labor measured in PPP, representing the country's price advantage in the world market and *lhte* is the logarithm of the share of high technology exports in the country's total export, representing the specific effect of the world's demand growth over the country (see annex for information on data sources).

Alternatively, we test equation (3), where *te* stands for technological effect, *se* for structural effect and *ae* for adaptation effect, as previously defined.

$$g_{it} = \propto + \beta_1 y_{it-1} + \beta_2 te_{it} + \beta_3 se_{it} + \beta_4 ae_{it} + \beta_5 dcap_{it} + \beta_6 dulc_{it} + \beta_7 lhte_{i,t-1} + \mu_i \quad (3)$$

We run panel data regressions with fixed and random effects taking into account changes in three periods, 1986/1990 to 1991/1995, 1991/1995 to 1996/2000 and 1996/2000 to 2001/2005. Table 5 shows the descriptive statistics for the data.

Table 5. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
gr	99	2.154	1.685	-2.012	7.752
ly	99	9.795	0.581	7.528	10.596
lhte	99	1.855	1.029	-1.018	3.653
dulc	99	0.008	0.084	-0.353	0.267
dcap	99	0.053	0.140	-0.585	0.822
tot	99	0.252	0.618	-0.555	4.872
te	99	0.264	0.585	-0.560	4.451
se	99	-0.004	0.035	-0.116	0.121
ae	99	-0.009	0.050	-0.153	0.374
rta	99	0.953	0.237	0.132	1.621

Table 6 shows the results for the regressions. Equations (A) and (B) test for fixed effects and random effects the model presented in equation (2). The fixed effects model performed much better than the random effects. The restricted F-test is significant and the Hausman test allows for the choice of the fixed effects model. Like Fagerberg et al. (2007) the catching-up variable is negative and significant at the 1% level and so is the *lhte* variable that controls for higher rates of growth of demand[5]. However, the variable unit labor cost has a counter intuitive, though not significant sign. This result contrasts with Fagerberg et al. (2007) that finds the predicted sign. One probable explanation for this difference[6] may be the use of different models. Panel data may control for country specific effects that were being capture by such variable. Furthermore, as data are measured in PPP units, wages may be capturing the effects of currency valuation as countries grow. The *dcap* variable also does not confirm the predicted sign, though again the variable is not significant.

Table 6. Panel Data Regressions

	Fixed Effects (A)	**Random Effects** (B)	**Fixed Effects** (C)	**Random Effects** (D)
ly	-4.82***	-0.18	-5.30***	-0.16
	(-3.48)	(-0.48)	(-3.69)	(-0.42)
lhte	1.89***	0.10	2.04***	0.13
	(3.60)	(0.49)	(3.81)	(0.63)
dulc	2.01	2.46	1.10	2.13
	(1.09)	(1.34)	(0.59)	(1.16)
dcap	-0.20	-0.95	-0.54	-1.08
	(-0.20)	(-0.90)	(-0.52)	(-1.03)
tot	1.04***	1.11***		
	(3.13)	(4.00)		
rta	2.17***	1.37**		
	(2.98)	(1.98)		
te			1.31***	1.25***
			(3.27)	(3.56)
se			12.91***	8.50*
			(2.57)	(1.83)
ae			-4.09	-1.48
			(-1.06)	(-0.41)
cons	43.52	2.20	49.99	3.23
	3.33	0.60	3.68	0.87
r2	0.40	0.2351	0.39	
F(6,60)	6.68		5.49	
Wald		28.26		27.22
F(32, 60)	2.32		2.23	
Groups	33	33	33	33
Obs	99	99	99	99
Hausman		69.56		18.22

However, the focus of the regression is on the behavior of the two technological variables. Both technological variables have the expected signs and are significant in equation (A). An increase of one standard deviation in tot implies an increase of 0.64% in per capita GDP growth per annum. The *RTA*

[5] One should be aware that lhte may also show spillover effects as is argued in ECLAC (2007) where they show that high tech sectors – though measured slightly differently – have a positive influence on GDP per capita growth, arguing for the effect of knowledge or learning by doing spillovers to other sectors.
[6] Apart from data and sampling differences.

also shows a strong effect on per capita GDP growth. If one increases *RTA* in one standard deviation there is a positive impact of 0.51% per annum in GDP per capita rate of growth.

Similar conclusions may be taken out of equation (C)[7]. The ly, lhte, dcap and dulc variables have similar results as those obtained in equation (A). Let use fix our attention in the shift-share variables. The technological effect (te) is positive and significant as expected and the impact of a change of one standard deviation in the variable over GDP per capita annum growth (0.73%) is similar to the effect of the tot variable of equation (A). The structural effect (se), which plays a similar role as RTA, also is positive and significant and has an impact of similar size, 0.45% per annum, on per capita GDP growth. These results seem therefore to support the idea that technological specialization matters. However, one should be aware that the way they stand in the regressions, they have suffered a change towards new technologies each five years. This sheds some light on the idea that technology choice may be policy oriented. In fact, technology leadership has varied to quite surprising areas during the three periods here analyzed.

Concluding Remarks

This paper aimed to contribute for the discussion about how technological specialization matters to growth. Literature on this issue hypothesizes the existence of a correct patterns of specialization, associated with the presence of high technological opportunity. The literature argues for at least three transmission channels for this curse or blessing of specialization: high TO technologies allow for the development of industries that take advantages of high productivity rates of growth, have positive spillover effects over the economy and stimulate the export of high-tech products that are have high income elasticities and, thus, high exports growth rates.

Literature also considers that technologies with elevated TO can be measured by the rate of growth of patents. However, literature has concentrated its policy prescriptions towards a certain set of technologies that are preconceived as having high TO, such as electronics and telecommunication paradigm. This has an important normative implication, especially for developing countries. Following this characterization of technological opportunities, the most usual recommendation for developing countries is to follow the South Korean example, that is, a change of the technological profiles towards a specialization in the electronics and telecommunications paradigm that would permit the benefits of correct specialization.

The paper shows that the technological dynamism of each technology varies across very short periods, such as five years. Furthermore, the paper indicates that changes follow a trend that show emerging and falling technologies and open room to capture effects of the complexity of technology, its pervasive effect and complementary character. The observation of evolution of the most fast growing technologies for each five years from the mid-eighties shows the pervasive effects of each paradigm (mainly electronic, telecommunications and medical-biotechnology) on other technical fields. From nineties, fields like Engines and Pumps, Medical technologies, Control and measuring technologies, Transport, Oil and Basic Material Chemistry, Material processing, Mechanical Elements, or even Food and Agriculture and Consumer Goods. This is because technological opportunity is dynamic across technical fields. As technological paradigms are exploited, they spread to other fields of knowledge, offering new opportunities to old technologies. This is an alternative way to look and calls attention to missing opportunities that may occurs for developing countries that can adapt the technology-push effect of new technological paradigms to their own specificities of production and markets by developing

[7] Again the fixed effects model shows the best fit.

absorptive capacity in these technologies and recurring to complementary mature technologies where they have been previously specialyzed.

Under this understanding of technological opportunity, it is not surprising the fact that initial technological specialization in fast-growing technologies is not necessarily associated with the path followed by countries. Furthermore, it shows why a particular wrong specialization does not lock the country in to low rhythm of technological activity.

The paper also tested for the hypothesis that correct specialization renders greater rates of growth. The overall results confirm the hypothesis showing that previous specialization in fast growing technologies has had a positive and significant effect on per capita GDP growth. In order to take this conclusion the paper used a panel data with fixed effects model. However, under the observations made above, one has to be quite wary about what he/she understands about *correct* specialization. As fast growing technologies have changed across periods, only few countries remained *correctly* specialized across periods.

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Annex

Sources of Variables in Tables 4 and 5

Variable	Description	Source
y1	Real GDP per capita (Constant Prices: Chain series) 1986-90	PWT6.3
y2	Real GDP per capita (Constant Prices: Chain series) 1991-95	PWT6.3
y3	Real GDP per capita (Constant Prices: Chain series) 1996-2000	PWT6.3
y4	Real GDP per capita (Constant Prices: Chain series) 2001-2005	PWT6.3
HTE1	Percentage of High Tech Exports in Total Exports, average 1988-1990	WDI 2009
HTE2	Percentage of High Tech Exports in Total Exports, average 1991-1995	WDI 2009
HTE3	Percentage of High Tech Exports in Total Exports, average 1996-2000	WDI 2009
HTE4	Percentage of High Tech Exports in Total Exports, average 2001-2005	WDI 2009
w1	Wage rate, average 1986-1990	EPWT 3.0
w2	Wage rate, average 1991-1995	EPWT 3.0
w3	Wage rate, average 1996-2000	EPWT 3.0
w4	Wage rate, average 2001-2005	EPWT 3.0
PROD1	Labor Productivity 1986-1990	EPWT 3.0
PROD2	Labor Productivity 1991-1995	EPWT 3.0
PROD3	Labor Productivity 1996-2000	EPWT 3.0
PROD4	Labor Productivity 2001-2005	EPWT 3.0
RTA1	Revealed Technological Advantage 1986-1990 to 1991-1995	EPO
RTA2	Revealed Technological Advantage 1991-1995 to 1996-2000	EPO
RTA3	Revealed Technological Advantage 1996-2000 to 2001-2005	EPO
RTAB	Revealed Technological Advantage Base Year 1986-1990 to 2001-2005	EPO
ETO1	Rate of Growth of National Patent Share 1986-1990 to 1991-1995	EPO
ETO2	Rate of Growth of National Patent Share 1991-1995 to 1996-2000	EPO
ETO3	Rate of Growth of National Patent Share 1996-2000 to 2001-2005	EPO
dCAP1	Share of population over 25 years old with at least 2nd education completed, 1990	Barro and Lee
dCAP2	Share of population over 25 years old with at least 2nd education completed, 1995	Barro and Lee
dCAP3	Share of population over 25 years old with at least 2nd education completed, 2000	Barro and Lee
dCAP4	Share of population over 25 years old with at least 2nd education completed, last year available	UNESCO