Technology and Specialization: Dilemmas, Options and Risks?

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1. Introductory remarks

Technical change and innovation have been powerful engines for enhancing dynamic specialization advantages of firms and industries, constructing ‘differences’ vis-à-vis competitors (within and between industries, regions and national or international spaces) and achieving cumulative growth, rents and power. In a period of crisis, specialization strategies can be conducted in ways that also enhance innovative specializations and competitive advantages in the post-crisis period, facilitate repositioning strategies and underpin answers to severe global risks (e.g. energy shortage, climate change).

In the past the construction of differences was considered to be mostly based on favorable cost and price structures and policies favoring price competitiveness. From the policy view, protectionism, subsidies, infrastructures and institutional arrangements have been the most apparent instruments for transforming specializations into competitive advantages in international markets. Major changes, among which the economic crisis of the 1970’s, the liberalization of the international markets and globalization caused a shift of analysis from price to technological competitiveness. It became increasingly apparent that the competitive advantages of countries and firms more and more had to be attributed to the accumulation of R&D activities and new knowledge, which allowed new combinations of factors. In this more recent period, R&D, technology and innovation policies, constitute a systemic tool for the creation of new knowledge and for a continuous differentiation of this knowledge, in the aim to create differences and new competitive advantages.

Following changes in the real world, theory[4] moved from the prevailing concept of “given and static comparative advantage” to the notion of “constructed and dynamic competitive advantage”. The new concept acknowledges that advantages are not only given, but can also be the outcome of evolutionary processes or, even more, can be created through public and/or firm actions and consequently can open new paths of specialization. In other words, specialization besides being linked to historic production patterns and path-dependencies, could also be regarded as a vehicle for a path-creating process.

In a system in which knowledge and technical change became determinant factors of market positions and competitive advantages, what is at the center of interest is how static conditions are complemented or substituted by more dynamic ones and how they can enhance an evolutionary and growing economic landscape, in the aim to be ahead of other actors and to avoid being outstripped from competitors.

2. Specialization and specialization policies: basic concepts and data

The most common use of the term “specialization” refers to the different weight the productive activities have in the production structure of a country. More specifically, technology specialization (and specialization in general) is a relative measure and can be specified through two different comparisons:

[4] In particular trade theory, from which the notion of specialization is taken.

- A comparison between the relative weight of the reference variable (scientific knowledge, research, technology outputs, patents and/or productive areas) within the same country, e.g. specialization in ICT, biotech, electrical engineering etc.,
- A comparison, respectively, between e.g. the above national technology specialization patterns to similar figures of third countries or areas.

Specialization by definition has two contrasting aspects: one *positive*, indicating the areas where a country, a sector and/or a firm exhibits a stronger position than other countries, sectors and/or firms, and one *negative*, indicating, respectively, the areas of relative weakness. Consequently, technology specialization in its positive sense inherently implies a *concentration of capabilities* on some areas of knowledge. Inversely, in its negative sense, it implies weak capabilities in other areas when compared to the pole of reference. The very concept of specialization, however, means that it is not conceivable that a country achieves specialization positions in the whole broad spectrum of technologies.

3. Why does specialization matters?

Specialization exerts different effects according to the technological level to which it is associated. A range of taxonomies can be discerned, such as:

- Specialization in scientific knowledge,
- Specialization regarding technologies and innovations,
- Specialization related to production processes,
- Specialization related to clusters,
- Horizontal vs. vertical specialization.

These different types of specialization are not only of an analytical nature. From our point of view they raise two questions: At which kind of technological knowledge have specialization policies to focus, to what extent these different levels require differentiated policies and of what type. For example, should technology specialization policies be examined with regard to research, development, innovation, or to clusters, to a mix of them or to other variables? The implications from specialization (as a policy goal or as a state) being localized in the early or the late phases of the R&D chain are very different. In particular, it makes an important difference whether specialization is embodied in production processes, leads to the creation of competitive advantages and affects directly growth, employment, income, welfare and power, or whether it remains at the sphere of scientific knowledge.

In the perspective of this paper, specialization acquires economic importance especially when new knowledge translates to value creation and is associated to the following conditions:

- it further strengthens accumulated technological capabilities, with positive effects on economic and/or social performance,

- it leads to the creation of new productive structures and competitive advantages,

- it has the potential to mobilize scientific knowledge generating dynamic processes of productive transformation and new competitive advantages.

The focus on the interrelationship between technology specialization and the creation of competitive advantages implies that it is not sufficient to examine just the innovative nature of knowledge. What matters is the ways new knowledge and technical change are integrated and assimilated in productive processes and with what results. Such a view allows a widening of the context in which technology policies are analyzed, that is the creation of new scientific knowledge, new technologies, innovations and the development of new dominant and emerging technology areas. Moreover, it is important to consider that new knowledge and technology are not related to specialization in a linear way, that the possible combinations of knowledge and technologies and their future uses and implications are unpredicted and can lead to competitive advantages of very different nature and in very different environments.

This means that the point at issue is not only technological. It is of a more complex nature, linking effective governance, coordination of research and technology policy, knowledge building and the shaping of productive processes. Specializations are not constructed only from knowledge inputs, related to technological change and innovations, leading to new products and/or processes. Concurrently to these factors, it is important to consider the «classical functions» of production processes, in which technological inputs are associated with very diverse locally available labour, capital, other inputs and, in particular, the prices of these inputs in different combinations. In such a framework, the ‘game’ of who can create competitive positions becomes complicated. The same knowledge permits producing firms to achieve very different combinations of the various elements of the value chain and hence to construct “differences” and competitive advantages through several specialization forms. Early-entrants are often advantaged. However, in the process of time, imitators can also be successful, even vis-a-vis the original innovators, to the extent that through a smart use on the one hand of these new technologies and on the other hand of their production value chain, they succeed to create specific or niche competitive advantages. In such cases, different rational behaviors lead to different efficiencies and might open windows of opportunities resulting to a change of previous hierarchies of competitive advantages.

Such a differentiating attitude allows also a more flexible approach to policy issues regarding leading players and followers. Obviously, technologically leading countries and firms are the environment in which most evolutionary or more radical technical change develop. These actors possess the research capabilities to generate new technology paths and to better benefit from such policies. In contrast, followers and laggards may be disadvantaged in all dominant and emerging technologies. What could be the policy consequence? That the efforts of laggard countries and firms to catch-up in these areas are condemned to lead to inefficiencies and a waste of resources? That there is no scope for policies enhancing advanced technologies in view of catching-up? A positive answer would be very deterministic, and history is plenty of examples of followers who were quite successful in imitation or adaptation strategies. Besides, all the significant efforts of the EU and national governments to diminish the gap to technology leaders in ICT or other areas indicate that specialization policies matter.

Comparisons of specialization patterns and competitive advantages between leaders and laggards need to be regarded from different points of view. For example, even within these two groups very diverse research and technology capabilities and specialization characteristics can be observed. In fact, the EU members, according to their R&D intensity (GERD as % of GDP, 2006) can be classified in four main clusters (or “clubs”):

- above 2,5% (Sweden, Finland, Austria, Germany),

- 1,5% to 2,5% (Denmark, France, Belgium, UK, Netherlands, Slovenia, Czech Republic),
- 1% to 1,5% (Hungary, Italy, Estonia, Spain, Ireland, Luxembourg), and
- below 1% (Portugal, Lithuania, Latvia, Greece, Poland, Malta, Bulgaria, Slovakia, Romania, Cyprus)[5].

To restrict the comparison between followers and leaders in the aim to draw policy conclusions on specialization approaches would be insufficient. Technological capabilities, specializations and competitive advantages should not be categorized in dichotomous terms such as leaders-followers or strong-weak. As useful this distinction can be for other reasons, in this case it would disregard the fact that the concepts of strong and weak are relative ones. Specialization and competitive advantages of a country or firm can at the same time be *weak* and *strong*. Weak vis-à-vis the upper side of the pyramid and strong vis-à-vis other weaker followers. A different view results when we compare specialization patterns and competitive positions of followers to the "upper cluster" than to countries and firms with inadequate specializations and weaker competitive positions.

Finally, it can be argued that specialization is not only the result of the creation of knowledge and/or technologies, but also of the diffusion of such technologies and the capabilities of firms and countries to exploit them and to use them in different applications or in a broader productive scope. In all these cases we are faced with forms of imitation or adaptation or with complementary strategies, which create specializations even in apparently similar fields, but with diversified characteristics, leading to the pursued competitive "differences". A very large part of countries and firms in the international scene have been followers or laggards, but nevertheless they could advance through technology transfer, adaptation and imitation.

4. Measures of specialization

In the literature, the measurement of specialization originates in trade theory. A variety of specialization indices have been developed to capture the specialization of a country and various such indicators have been also used as technology specialization indices, of course after some adjustments.

The most common technology specialization indices have the following form:

Concentration indices, measuring the weight of the n more important sectors (n can take the value of 1, 3, 4, 6, etc) to the total relevant figure for a specific technology variable (e.g. R&D, patents). The concentration ratio is given by the following expression:

$$C(X)_j = \frac{\sum_{k=1}^{x} p(k)_j}{\sum_{i=1}^{n} p_{ij}}$$

[5] See also the distinctions in ch. 5.3.2.

where X is the number of the largest classes (e.g. level of 4 or 6 classes) to take into account, p_{ij} is the number of patents for application of country j in the ith technological class and p_{ij} is the kth largest number of patents per technological class[6].

b) Indices very closely related to the **Revealed Comparative Advantage Index** of the Trade Theory, taking the form:

- The Balassa Revealed Technological Advantage Index[7] (or specialization index) (SI) defined as following:

$$SI_{kj} = 100 * \tanh\ln\left[\left(X_{kj} / \sum_j X_{kj}\right) \Big/ \left(\sum_k X_{kj} / \sum_{kj} X_{kj}\right)\right]$$

where X_{kj} can indicate alternatively the number of patent applications, exports, etc. of country k in sector j. Positive values mean that the sector has a higher weight in the portfolio of the country than its weight in the area of comparison (e.g. EU). Negative values indicate specialization below the average.

- Alternatively: an index of technological specialization[8]:

$$MS_i^H = \frac{\sum_{j \in H} X_{ij}}{\sum_{j \in H} X_j} \qquad MS_i^L = \frac{\sum_{j \in L} X_{ij}}{\sum_{j \in L} X_j}$$

$$ITS_i = \frac{MS_i^H}{MS_i^L}$$

The index shows how much any particular country or region adapts its relative high to low-tech products trade structure to changing patterns of world trade in high and low technology products.

In the above formula i stands for countries (or regions), j stands for SITC products, MS stands for share in the world market, H is the set of high-technology product groups, L is the set of low-technology product groups, X_{ij} is the value of exports to the world from country i in product group j, X_j is the value of exports to the world from all countries in product groups j. Comparing ITS in different time periods shows how a country's relative market share in high and low technology change. A value below (above) one indicates that a country's

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[6] See N. van Zeebrock et al., (2006), Issues in measuring the degree of technological specialization with patent data, Scientometrics, 66, Nr.3, p. 484.

[7] See Erawatch, (2006), R&D Specialisation. Methodology and Data used.

[8] L. Alcorta, W. Peres, (1998), Innovation systems and technological specialization in Latin America and the Caribbean, Research Policy, 26, pp.873.

export share in high technology markets is higher (smaller) than its export share in low technology markets. An increasing (decreasing) value for ITS along time indicates a movement towards a relatively higher (lower) market shares in high technology markets.
The other above indices also can be adjusted so that they can measure the *changes of technology specialization* over time.

All these indices measure if and to what extent the observed country, region, firm or supra-national area exhibits *a higher concentration of the chosen variable* in areas where they possess a specialization than other competitors. The reasons and the process towards this specialization and the influence of factors such as the public, private or mixed nature of public resources, the role of institutions and other factors cannot be answered by this empirical observation. However, from a policy point of view, it is important to understand how specialization positions could be achieved and what is their specific economic or social impact.

5. R&D Structure and specialization patterns: the landscape in the E.U.

5.1. A general view of R&D specialization in the technological advanced E.U. countries

In Table 1 data are presented on the distribution of R&D expenditures in eleven member countries for the manufacturing sector[9]. Manufacturing industries are presented at the 2-digit level, which is a very general level. Two remarks can be made:

A small number of manufacturing branches attracts the interest of most of the above countries. Pharmaceuticals, Machinery & Equipment, Radio-T/V-Communication Equipment and Motor Vehicles are areas which attract significant shares of R&D expenditure in nearly all eleven countries. This implies that countries (and firms) attempt to gain specialization in established technological areas, in the aim to exploit established competitive positions and windows of opportunities. As a result, national specialization patterns of countries belonging to the same cluster exhibit many similarities when specializations are examined at a general sectoral level. In reality, specializations are much more diversified when one looks at a more disaggregated level within these broader knowledge and technology classifications, implying that in fact national systems create specific and differentiated specialization poles. However, only a limited number of countries seem to specialize in some high tech industries (aircraft, office & computing machinery).

All countries exhibit a very high sectoral concentration of R&D expenditures. In nine countries 2 to 5 sectors concentrate 46% to 77% of total R&D. In four of these countries only 2 or 3 sectors concentrate 55% to 70% of total R&D.

[9] The data refer to the EU-15. The countries not presented are Austria, Greece, Luxembourg and Portugal.

Table 1: Distribution of R&D expenditures in total manufacturing by industrial sectors
Distribution of R&D expenditures across industries for total manufacturing (RDSMAN), 1999

	ISIC	BEL	DNK	FIN	FRA	DEU	IRL	ITA	NLD	ESP	SWE	GBR	aggregate share	mean share	median share
TOTAL MANUFACTURING	15-37	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
Food products, beverages and tobacco	15-16	3,3	4,1	2,3	2,1	0,7	7,5	1,6	7,7	3,7	1,0	2,6	2,0	3,3	2,6
Textiles, textile products, leather and footwear	17-19	1,8	0,4	0,5	0,6	0,7	0,7	0,3	0,5	2,2	0,1	0,3	0,6	0,7	0,5
Wood, paper, printing, publishing	20-22	1,2	0,8	4,5	0,5	0,4	1,6	0,4	0,9	1,6	2,8	0,5	0,8	1,4	0,9
Coke, refined petroleum products and nuclear fuel	23	2,4	0,0	0,6	1,6	0,2	0,0	0,4	1,1	1,5	0,3	2,4	1,0	1,0	0,6
Chemicals excluding Pharmaceuticals	24x	21,3	5,8	3,8	7,1	11,8	4,1	6,5	15,4	7,1	1,9	8,0	9,2	8,4	7,1
Pharmaceuticals	2423	21,6	38,2	4,8	15,4	6,8	14,0	10,9	12,9	12,2	19,3	28,2	14,4	16,8	14,0
Rubber and plastics products	25	2,9	3,6	2,1	3,3	2,0	2,0	2,2	1,3	3,4	0,8	0,8	2,1	2,2	2,1
Other non-metallic mineral products	26	2,5	1,0	0,8	1,5	1,1	1,2	0,3	0,5	2,2	0,3	0,7	1,0	1,1	1,0
Basic metals	27	4,0	0,4	1,6	1,6	0,8	0,3	0,6	1,9	2,0	2,3	0,7	1,2	1,5	1,6
Fabricated metal products	28	1,6	1,4	1,9	1,2	1,7	1,2	0,8	1,7	2,6	0,4	0,8	1,3	1,4	1,4
Machinery and equipment, n.e.c.	29	6,4	16,6	11,1	5,2	11,1	3,8	9,5	10,5	9,1	10,2	7,1	8,9	9,1	9,5
Office, accounting and computing machinery	30	0,2	1,4	0,4	2,2	2,1	6,8	1,2	31,8	2,8	0,8	1,2	3,0	4,6	1,4
Electrical machinery and apparatus, nec	31	4,2	4,9	5,7	4,3	3,3	6,2	3,1	2,3	5,8	1,6	4,0	3,7	4,1	4,2
Radio, television and communication equipment	32	18,1	6,6	55,9	14,6	11,9	40,8	25,6	1,1	11,9	27,4	9,6	15,0	20,3	14,6
Medical, precision and optical instruments	33	1,6	10,1	2,3	7,9	5,4	6,6	3,6	5,1	2,6	6,7	5,3	5,6	5,2	5,3
Motor vehicles, trailers and semi-trailers	34	4,8	0,8	0,5	15,6	30,8	1,6	16,9	3,9	12,1	19,9	11,8	19,1	10,8	11,8
Building and repairing of ships and boats	351	0,0	2,4	0,4	0,1	0,1	0,1	0,4	0,3	3,3	0,1	0,8	0,4	0,7	0,3
Aircraft and spacecraft	353	1,1	0,0	0,0	13,7	7,3	0,5	14,2	0,3	9,9	3,4	13,8	9,1	5,8	3,4
Railroad equipment and transport equipment n.e.c.	35x	0,1	0,0	0,3	0,6	0,9	0,0	1,1	0,3	2,0	0,4	1,1	0,8	0,6	0,4
Manufacturing nec	36-37	0,6	1,5	0,5	1,0	0,6	0,8	0,3	0,5	2,2	0,2	0,4	0,7	0,8	0,6
High-technology manufactures		42,7	56,2	63,4	53,8	33,6	68,7	55,5	51,3	39,3	57,5	58,1	47,1	52,7	55,5
Medium-high technology manufactures		36,8	28,0	21,4	32,8	58,1	15,8	37,1	32,3	36,1	34,1	32,0	41,7	33,1	32,8
Medium-low technology manufactures		13,5	8,9	7,4	9,3	5,9	4,9	4,7	6,7	14,9	4,2	6,1	7,1	7,9	6,7
Low technology manufactures		7,0	6,8	7,8	4,2	2,4	10,7	2,6	9,7	9,7	4,2	3,8	4,1	6,3	6,8

Source: OECD STAN Indicators database, 2005
Data for 1999. 11 EU countries. Percentages are shown.

5.2. Technology intensity of trade specialization of 8 E.U. countries

In Tables 2-4 a comparison is made between the specializations of some technologically leading and some weaker countries of the EU. In particular, data in these tables present the technology intensity of exports and imports as well as the competitiveness of these countries classified in five distinct categories according to their technology intensity[10].

The observed specialization patterns allow the following conclusions:

Firstly, the EU landscape is very heterogeneous in terms of technological capabilities. Heterogeneity has many aspects and is observed not only in the differences between advanced and less advanced countries, but also in the different structures between countries of the same cluster.

[10] Based on OECD and E.U. classifications.

Second, while the three Mediterranean countries are all characterised by similar weak competitiveness with regard to the medium to high-tech industries, there are large divergencies regarding the competitive performance of the most advanced countries.

Third, as a result of teir weak position in medium and high tech industries, the technological less advanced countries suffer from overall trade deficits, since their technological disadvantages cannot be counterbalanced by stronger competitive positions in the technological less intensive export categories.

Table 2: Technology intensity of the export structure (2006)

Products	Greece	Spain	Portugal	Ireland	Germany	France	UK	Netherlands
Agricultural products & Raw material	10,8%	6,6%	5,9%	9,0%	4,4%	7,6%	3,9%	12,3%
Low technology	24,3%	19,9%	24,4%	8,8%	11,9%	15,3%	11,6%	13,6%
Low-Medium technology	40,3%	23,5%	30,1%	2,6%	17,5%	17,7%	21,9%	23,9%
Medium-High Technology	14,1%	42,3%	31,3%	42,4%	53,3%	47,9%	35,7%	27,8%
High Technology	7,9%	6,5%	6,0%	33,6%	9,7%	9,8%	22,9%	17,7%
TOTAL	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

Source: T. Giannitsis et al., Competitiveness and Technology in Greece (2008, in Greek), Calculations based on Eurostat data.

Table 3: Technology intensity of the import structure (2006)

Products	Greece	Spain	Portugal	Ireland	Germany	France	UK	Netherlands
Agricultural products & Raw material	8,9%	9,2%	10,3%	6,6%	7,1%	6,3%	6,4%	9,1%
Low technology	14,6%	12,5%	16,2%	14,3%	13,2%	14,6%	14,9%	13,2%
Low-Medium technology	34,6%	31,1%	31,4%	18,6%	28,3%	30,6%	22,6%	30,5%
Medium-High Technology	30,4%	37,1%	32,1%	30,5%	37,1%	37,1%	29,7%	26,4%

Source: As in Table 2.

Table 4 : The Balassa Index of Specialization by technology groups for EU countries, 2006

Products	Greece	Spain	Portu-gal	Ireland	Germa-ny	France	UK	Nether-lands	Sweden
Agricultural products & Raw material	-0,428	-0,366	-0,455	0,360	-0,142	0,046	-0,377	0,203	-0,159
Low technology	-0,291	0,015	-0,010	-0,025	0,048	-0,024	-0,264	0,070	0,198
Low-Medium technology	-0,443	-0,342	-0,232	-0,639	- 0,140	-0,311	-0,159	-0,065	-0,086
Medium-High Technology	-0,734	-0,149	-0,223	0,366	0,274	0,080	-0,055	0,080	0,112
High Technology	-0,619	-0,388	-0,391	0,377	-0,026	-0,100	0,073	-0,005	0,195
TOTAL	-0,502	-0,213	-0,211	0,215	0,099	-0,048	-0,145	0,055	0,076

Source: As in table 2.

5.3. The E.U. R&D regional landscape

In the recent past some several studies about regional R&D systems[11], R&D intensities as well as about regional R&D specification have been published.

With respect to possible future policy considerations it seems beneficial to recall some of the outputs of these studies.

5.3.1. R&D intensities on NUTS 1 level and specification patterns

With regard to this level of regional classification three categories of specialization patterns have been distinguished:

a) Regional R&D intensities;

b) Scientific specializations, and

c) Technological specializations.

5.3.1.1. Regional R&D Intensities

Overall GERD:

- As expected R&D Intensities show high variances between the regions. They differ between 4,16 GERD in % of GDP for Baden-Würtenberg/ GE and 0,12% in Severna/BG. at NUTS 1 level and an 8,7% (Braunschweig /GE) and 0,1% (Swietokrzyski/PL) at NUTS 2 level[12],
- Out of 79 regions only 5 regions have achieved the Lisbon goal of at least 3% of GERD as of 2005. And even worse, only 17 have an R&D intensity of more than 2%, while 29 regions show a R&D intensity of less than 1%.

BERD

- The figures show that the regions with the highest BERD expenditure are concentrated only in a few Member States.

- Even if one extends the list of regions to all regions which perform a BERD just above EU average, they are concentrated in only nine Member States , ten in Germany, six in France, four in UK two in Austria, Belgium and Spain, and each one for Italy, Finland and the Netherlands.

- In most of the TOP performing regions the R&D expenditures are financed and controlled by the business sector. The main exception is Berlin, which has an extraordinary high public expenditure (probably because of the Max Planck Gesellschaft), a fact which is certainly connected with the post war history of Berlin.

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[11] Fraunhofer Gesellschaft (ISI) recently published two studies: H. Kroll, Th. Stahlecker "Regional Key Figures 1-2008; V. Peter, R.Frietsch:"Exploring regional technology specification;

[12] Tables and the Annex are omitted.

- **The 10 NUTS 2** regions with the highest BERD in absolute terms count for 40% of total BERD expenditure in the EU.

- The majority of regions being listed under the TOP10 for one indicator are also listed under the TOP 10 for other indicators. Two regions (East England, Ile de France) are quoted six times, four regions (Baden-Würtenberg, Bayern , Manner Suomi, UK South East) five times, Berlin four times, three regions (Bremen, Hessen Zuid Netherlands) three times, three regions (Brussels, London, Centre East France) two times, and nine regions only once.

- Public R&D expenditure has stabilized the overall expenditure during the economic downturn.

- Government support is relatively (with respect to overall R&D expenditure) high in the regions lagging behind, compared with those regions having a high GERD, probably with the exception of Berlin.

- The figures show also, that the numbers of regions which are dominated by expenditure for higher education and government sector research are small compared with those, dominated by the business sector. Nevertheless, there is also a number of broadly based innovation systems which are neither completely business nor completely public sector dominated.

*5.3.1.2. Scientific specialization (*measured by publications)[13].

Scientific publications can be seen as a mirror of the scientific expenditure priorities of an entity, region, or country. Scientific publication activities of the Member States can be characterized as follows:

The regional distribution of scientific publication seem to be more influenced by the local presence of academic centers, and shows a different geographical pattern and is less concentrated than business R&D expenditure. It includes peripheral regions like Scotland, coming down via Paris and the Benelux to Baden Würtenberg and up again via Berlin to Sweden and Finland.

With respect to field specialization most of the countries show a positive specialization in fields like Chemistry, Mathematics and Physics, while a negative one must be recorded in fields like basic Life Science, Biomedical Science, Clinical Medicine, Earth and environment.

5.3.1.3. Technological Specialization

The regional data about patenting are - not surprising – very similar to GERD and BERD expenditures. Sweden and Bayern are in the TOP group, as well as Brabant (Philips), Ile de France, Zuid NL, South East UK, Baden- Würtenberg, Berlin.

[13] Specification indices referred here inform us about relative specification, i.e. to the countries (EU or world) average; it does not consider the absolute levels or the industrial structure of a region.

Nevertheless country specifics can be derived. Even most of the countries are above the world average in the technology sectors, like transport, special machinery, which are congruent with the findings of the scientific specialization index, a few countries show a different specialization pattern. Finland shows a positive specialization only in two segments (Telecommunications and measurement system), Sweden in Medical equipment and machine tools, while Germany is not specialized in high tech industries at a country level, but focuses on medium high tech segments, like mechanical engineering and transports.

The figures show that for industries, like Electrical Engineering, Instruments, Communication Technologies and Biotechnology positive specialization is concentrated to a few regions, while for the bulk of industries the majority of regions show a positive specialization index. For example, within the sample of first 100 regions (listed according GERD), 81 regions show a positive specialization index for Mechanical Engineering, 63 for Chemistry, 73 for Transport, while the number for Electrical Engineering and ICT is 33 for each, for instruments 34 and biotechnology 44.

On a regional level there is much evidence that the positive specialization in high tech industries is concentrated in Scandinavia, South Netherlands, East UK and some regions n Germany.

These regional results are mirrored in the overall specialization index of the EU, which shows a broad specification in mid-tech industries, while the specification index is negative in segments like Pharmaceuticals, Medical Instruments, Media Equipment, Optical Instruments.

5.3.2. Regional typologies of RIT system

The key aim of this clustering is to distinguish:

- between regions in which the data suggest that they are R&D driven,
- those where it plays a supportive role, and
- those where it is only complementary to the local economy.

The question of whether the regional research system plays a role with regard to the national innovation system is material to understand its function in the ERA system.

The following typologies can be distinguished:

Outliers: high R&D intensity, very high BERD/ GERD ratio, patent intensive; R&D activities dominated by large companies. R&D expenditures in all 6 “outlier” regions are dominated by large corporations (VW, Philips, Nokia); outlier regions are situated in Germany, Finland, Sweden and the Netherlands.

Type 1a: Broadly based R&D driven regions. Moderately high publishing and very high patent intensity: German Cities, the capital regions of Vienna and Ile de France as well as regions bordering to London, the state of Denmark and prosperous urban regions in Germany and France.

Type 1b: Business oriented R&D driven regions. Very high patenting and publishing intensity: Among them German regions like Tübingen, or cities like Karlsruhe, Scandinavian regions like Stockholm, and Southern Finland.

Type 2: Public sector centered R&D supported regions. Very high publishing and slightly over average patenting intensity: mainly capital regions (high public expenditure) like Prague, Bratislava, London and some university towns in Austria, Germany Netherlands and the UK.

Type3a: R&D supported regions, comparatively public sector oriented. Average publishing patenting and publishing intensity, but slightly higher publishing and somehow lower patenting intensity.

Type 3b: R&D supported regions, comparatively business oriented. With lower publishing and higher patenting intensity.

Type 4a: R&D lagging behind, public sector oriented. Near absence of patenting, very low business sector intensity: new member states as far as values are available.

Type 4b: R&D lagging behind, business oriented. No sizable public research activities.

As to be expected, differences in R&D intensities at the NUTS 2 level vary widely: between 8,7% in Braunschweig and 0, 1% in Swietokrzyski. Based on the NUTS 2 classification, which is used for the typology clustering , the regions with the highest R&D intensity(GERD in % of GDP) are -with the exception of Berlin - not the large metropolitan cities, but regions which are dominated by a city (like Munich in Oberbayern, or Uppsala in South Sweden), or cites as such like Stuttgart or regions like Braunschweig, dominated by one big company (VW).

BERD dominates in the best performing regions. 8 of the 10 best performing NUTS 2 regions in respect to GERD in % of GDP figure also under the TOP 10 regions in respect to BERD in% of GDP,

Among the regions with the highest Public R&D intensity (Government and Higher Education), only 4 are listed under the overall 10 TOP performers.

South Europe: astonishingly many Type 4 regions, Portugal: 4, Italy: 13 (out of 21), Spain: 13 (out of 17).

Typology of European NUTS 2 regions, Average[14] Values by Type

		Publications per Million inhabitants (2003)	**Patents per Million inhabitants** (2001)	**GERD as % of GDP** (2003, UK 1999)	**BERD as % of GERD** (2003, UK 1999)
Outliers	n=6	1497.8	579.9	5.24	83.52
Type 1 Region	n=25	1843.4	323.0	3.23	67.49
1a	n=19	1616.9	284.4	2.98	66.64
1b	n=6	2560.6	445.3	4.00	70.18
Type 2 Region	n=16	2393.4	114.4	1.64	37.14
Type 3 Region	n=59	806.2	121.1	1.40	62.17
3a	n=37	916.6	88.7	1.22	52.21
3b	n=22	620.6	175.7	1.68	78.94
Type 4 Region	n=84	379.3	32.3	0.66	45.76
4a	n=54	465.9	17.3	0.62	28.51
4b	n=30	223.5	59.2	0.72	76.82
Total (including Outliers)	n=190	**909.5**	**122.3**	**1.45**	**54.19**
Total (excluding Outliers)	n=184	**890.3**	**107.4**	**1.33**	**53.23**

Shadings:
dark green: > 100% above average, light green: 25-100% above average
dark red: >50% below average, light red: 25-50% below average.

Source: Own compilation from the Regional Key Figures, 1-2008, European regional research system: Current trends and structures; H. Kroll, Th. Stahlecker; Fraunhofer;ISI

5.3.3. Summary

Regional differences in R&D intensities in Europe are mainly influenced by BERD expenditure. Only in a few of the TOP R&D performing regions public sector expenditure is high enough to influence the overall GERD significantly (for example: Berlin).

[14] Unweighted means.

There are only a minority of regions which can be classified as R&D driven (27 out of 190) and only in a few of them is the public sector expenditure an important source.

Scientific specialization seems to be more influenced by public expenditure (influence of large regional universities) than other indicators.

Regions lagging behind have a lack of academic institutions and of higher education which diminishes also their ability to absorb knowledge from abroad and to improve innovation significantly. This is true for most of the Type 4 regions.

At the country level, the figures suggest that the Nordic countries are those which have the highest specialization in high tech industries. For example Finland shows a positive technological specification in two high tech industries, namely Telecommunication and Measurement Control, and a negative specification in 8 (low and mid tech) industries. Denmark shows a positive specialization in Pharmaceutical Industry and Consumer Industries, Sweden in Medical Equipment and Machinery Tools, while the Netherlands is strong in Audio-visual Electronics, Telecommunications, Optics. In the contrary Germany seems to be very strong in the medium-tech industry[15].

Cities with large u5 niversities or other excellent R&D infrastructure seem to have an advantage in attracting R&D personnel as well as R&D funds. ("Hot spot": Berlin).

Not surprising that a number of metropolitan areas are quite successful (Paris, London, Berlin, Brussels). This raises the question how much agglomeration counts for R&D; agglomeration does not necessarily mean concentration to one field of science or to one specific industry but can also be seen as a horizontal approach ("Related varieties" : many of the high tech clusters focus on several research fields; for example the Helsinki region is focusing on nine technology fields[16].

6. Technological-led specialization as a wider E.U. policy issue

At both the E.U. and the national level the question of specialization policy cannot be answered generally[17]. The E.U.-27 consists of divergent national and regional situations, which very often make necessary differentiated policy answers even for apparently similar problems. In addition to these internal disparities the E.U. is disadvantaged because of its laggard position in a range of high-tech/core technology areas vis-à-vis world leaders, with adverse consequences in terms of productivity, growth, market positions and business strengths. One of the visible weaknesses of the E.U. is its difficulty to be path-creating or early entrant in a range of new technologies, to make more efficient use of some of these technologies, to achieve similar productivity results, to diffuse sufficiently such new technologies inside its space and to create a culture of technology and knowledge widely spread in the member states.

Both these types of divergence are at the origin of many policy concerns at both the E.U. and the national level, such as:

[15] Attention should be drawn to the fact that technological specification as calculated by ISI strongly reflects the influence of the industrial structure; further the application for patents is not independent from the specific industry.

[16] "Forschungsstandort Österreich", Comparison of high tech. regions.

[17] A question of different nature concerns the distinction of national and EU competences in the area of RIT policies. The analysis here is focusing on the normative aspects of policy, making abstraction of existing institutional limitations.

- Any initial laggard position, as was the case with ICT, calls for policies aiming at closing the gap either by enhanced research, technology diffusion and technology transfer or by developing leading capabilities in other emerging frontier technologies.

- The capability of the major E.U. players to be early entrants with regard to emerging technologies would influence positively their own and the E.U.'s competitiveness and growth potential in the years to come.

- Significant future global risks have to be faced at a world scale during the next few decades, especially with regard to energy, environment and climate change and their much broader implications (health, alternative social organizational schemes, transports etc).

As a consequence, the E.U. needs a diversified strategy with several strategic targets. With regard to the frontier technologies the E.U. has to prevent the likeliness to see once again the adverse experience with ICT, which led her in the position of a laggard. It appears that there is a structural barrier preventing Europe to become leader in emerging frontier technologies. The present forms of (mostly national) technology policies, as important they are, seem not able to cause a significant quantitative and qualitative upward shift of R&D activities in Europe. Despite political commitments, the 3% target cannot be approached. Even the less ambitious target to shift the R&D/GDP ratio over the past E.U. average of 1,9% can hardly be achieved. In crucial areas European technology advancement appears to be comparatively either "too little" or "too late". What is the policy lesson? Is it possible to reverse this trend and how? Can either a positive or a negative answer be given at zero social cost or risk? If not, what are the policy implications?

With regard to its internal gap and catching-up policies, the recent crisis showed how important for Europe is to narrow these internal technological divergences. A lesson to be drawn was that the persistence of large intra-E.U. technological gaps exerts also an adverse impact on the macro-performance of the E.U. (in terms of macro-imbalances, productivity levels and competitiveness). In fact, the present crisis raises the question why the technologically weaker countries are faced with deeper imbalances and drawbacks, to what extent their knowledge and technological base and capabilities are a crucial factor for their broader economic performance and how this affects the overall performance of the E.U. The present experience supports the argument, that although technological capabilities are not linearly related to the quantitative aspects of growth, they nevertheless can have a large impact on its qualitative aspects (structural imbalances and deficits, weak sustainability against shocks, ambiguous trade-offs between growth and other variables, such as debt, inflation, competitiveness).

In fact, external and internal divergences justify different mixes of specialization approaches rather than one-size-fits all strategies. The E.U.'s strategies are focusing on three major challenges:

- to make of the E.U. "the most dynamic and competitive knowledge-based economy in the world",
- to narrow internal discrepancies and enhance convergence, and

- to deal with global risks and prevent large systemic risks in areas of major public concern such as energy and climate change.

6.1. The issue of appropriate policy mixes

A range of contributions have shown the possibility (and the need) of plural and diversified approaches on specialization. Two debates merit a detailed consideration: the questions of neutral vs. targeted policies and of concentration vs. decentralization (or networking) of resources.

Neutral or horizontal policies are supposed to create general favorable conditions for market initiatives without discriminating and/or selecting between sectors or firms. They can be contrasted to pro-active or targeted policies, which follow more explicit, broader or narrower, objectives and, therefore, comprise some selection mechanisms. No-policy could be considered as a particular category, meaning the absence of any kind of policy action, although one could argue, that inaction is also a policy choice. In fact, to some extent, the absence of distinctive actions to tackle a specific problem, comes closer to the concept of neutral than to targeted policies.

Pro-active R&D and technological specialization policies are considered with skepticism because of two major policy drawbacks:

a) the failures of past interventionist industrial policies, and
b) the risks associated with pro-active policies in general and even more so in the case of research and technology policies.

As against these experiences, there are other elements which make necessary a reconsideration of the issue :

- The risks of the no-policy (or neutral) policy choices,
- The risk of retrogression in specific areas,
- The shaping of a more flexible fine-tuning of policies, which prevails in many other policy areas,
- The risks of the failure of the 'market' (as we see in the ongoing crisis), and
- The risk that externalities and/or public goods (spill-overs) are not correctly priced by the market.

Regarding the types of policy interventions today, the debate on neutral vs. selective_or targeted policies appears quite simplistic. Many types of policies at all levels explicitly or implicitly are envisaging the development of specific areas of research, technology and innovation. Even when public policies come to supplement the self-organising private initiatives, selectivity is often very present, although it is different if we refer to sectors, products, activities or firms[18]. On the issue we are faced with a big paradox and a dichotomy between theoretical approaches and widespread policies, because, in fact, all possible forms of policy –neutral, interventionist, horizontal, targeted- have experienced a broad mix of both successes and failures.

[18] Ch. Edquisit, Cr. Chaminade (2006), Industrial policy from a systems-of-innovation perspective (EIB papers).

6.2. The risks from neutral policies

Specialization policies either for strengthening existing industrial structures or for catching-up to technological leaders, but in particular for promoting emerging technological fields, are associated with risks of failure. This is half of the reality. The other half is that in absence of any action, risks are equally present. Inaction and/or neutrality can also have risks and costs. The difference to pro-active policies is of political, not economic, character. In cases of inaction failure cannot be directly attributed to no-policy. Hence, it takes not the form of a visible political cost, although it can have a high economic or social cost. To the extent that the speed with which the support of appropriate technologies can contribute to answering the global issues is of high importance, the rapidity of policy-making has a social value. In this case, what matters, is not only to avoid repeating the experience with ICT or other technologies, but to produce timely research results meeting extremely important global needs.

6.3. The risks from targeting specialization

For many authors, the capability to organize and to manage technological change and innovation is inherent to the above policy questions. Baumol[19] writes that innovation is "the recognition of opportunities for profitable change and the pursuit of those opportunities all the way through to their adoption in practice", while Drucker[20] argues that "innovation ..is the only way to convert change into opportunities. This requires that innovation itself be organized as a systematic activity".

While this type of management concerns mainly the business sector, public policies cannot escape the necessity to manage successfully technological and specialization activities. Often the policy rationale is structured around the concept of market failures and/or externalities. The following specific aspects need to be considered:

a) The sectoral nature of many types of technical change and innovations,
b) The objective to facilitate new technology paths and/or to replace repeated specializations by a specialization breakthrough, which can create significant competitive advantages,
c) The importance to enter early into a new technological area,
d) The timely development of capabilities in the aim not to be outstripped by competitors,
e) The acceleration of emerging evolutionary processes,
f) The enhancement of appropriate institutions, infrastructures, interactions, networks,
g) The presence of spillovers when an invention/innovation has a higher social than market (individual) value,
h) The public good aspects of certain R&D activities.

[19] W.J. Baumol (2002), The free-market innovation machine: analyzing the growth miracle of capitalism (Princeton University Press).
[20] P. Drucker (1994), Innovation and entrepreneurship (New York, 1994).

In all such cases the goals are unlikely to be successfully achieved without directed public actions. Private returns from investing in non-traditional activities can be highly uncertain, private response can be reluctant, and hence, some intervention could be appropriate.

The question is how policies can be effective in attending their targets. This is a general question on government efficiency. However, the question on the 'how' –the effectiveness dimension- of a specialization policy is also closely interconnected to the question of 'what'. What should specialization policies envisage? On the one side, an effective 'how' can be defined and implemented only if the 'what' is also clearly defined. On the other side, meaningful decisions on the 'what' cannot be disconnected from 'how' policy will be shaped. Policies in favour of ICT, energy, nanotechnology, climatic changes, health are always determined by the specificities of the objective and the capabilities of the innovation system to perform.

Basically, the main question is again how to be selective, what risks have to be taken and how efficient policies can be designed and implemented. In fact, both the 'what" and the 'how' point to the need for public policies to provide efficient or smart support to activities but also to anticipate for timely and efficient discipline in order to avoid 'picking the losers'.

The fact remains, that pro-active policies, even if based on market-evidence, are subject to similar risks of failure as horizontal ones. Besides successes, the experience is full of failed attempts to create Silicon Valleys, Third Italies or Science Parks. Apart from serendipity, there are two main factors causing success or failure. The first is the well known problem of public failures. The second is the inherent high uncertainty and unpredictability of foreseeing 'what a country will be good at producing' or 'where the advantages can lie'. Rarely could successful specializations be visible ex ante. Even countries with very similar levels of technological capabilities and factor endowments followed very different specialization patterns as a consequence of different historical evolutions, entrepreneurial initiatives and policy responses.

6.4. An horizontal issue: Concentration of resources versus decentralization approaches

The policy dilemma whether with regard to technology and/or geographical areas, resources should be concentrated around specific goals or be allocated in a more decentralized way, is continuously debated. However, the question is of a more general nature and is not specifically linked to technology policy. The same question has been the object of many other policy debates and is linked to many other concepts (such as indivisibility, critical mass, externalities or rational allocation of resources). It encompassed several theoretical approaches (e.g. the infant industry argument, the industrial pole theory, different other strands of the development theory) and, also, it has been an objective of various policy experiences.

Nevertheless, a concentration of efforts to enhance technological development, specific activities, sectors or regional centers is a very common policy practice, both at the national and the E.U. level. The issue in all these approaches is the degree of *relative concentration* and the *mix* between focused and decentralized support mechanisms. The policy question is whether we can specify conditions under which the one or the other policy mix should be privileged. Besides, such choices are subject- and time-dependent, and they don't prejudice choices on other policy issues, or even on the same issue in different time. Hence, concentration or decentralisation policies can coexist and be appropriate, depending on the specific environment. Concentration could be an appropriate tool for situations, in which the failure risks are relatively low and/or the expected benefits have a high social value. In contrast, decentralized approaches can be more relevant when unpredictability and uncertainties are high, or "let all the flowers bloom" policies are appropriate.

The concept of 'smart specialization' is right in its emphasis on the importance for countries not to imitate, not to duplicate or to reproduce specialization patterns which have been developed in many other countries and regions. However, one has also to take into consideration that what appears as a wasteful duplication can also generate competences which bring a country and/or firm beyond the stage of simple duplication and gives rise to unpredictable innovative capabilities and specializations.

In fact, although the vast majority of actors are technology followers or laggards, many of them succeed to build own new capabilities and competitive advantages around ICT, biotech, mechanical, chemical or other areas. What is crucial is that technology change is an open ended process related to a continuous expansion of the frontiers of knowledge, further changes and innovations, even in areas in which already many other actors lead. Hence, policy choices restricting followers for entering dominant areas of technology in the aim to avoid a possible duplication of actions and a waste of resources can be risky.

More generally, the view of specialization as a dynamic process indicates that in order to move from a weaker to a stronger (more competitive) specialization position and to ensure long-term advantages, what matters is the capacity to transform patterns of specialization, the capability to shift from existing to new specialization areas and the related more general concept of the capability to change.

Path-dependencies can facilitate such a shift and provide a relatively good basis for policy decisions. However, while path dependency can be an important explanation for specialization and competitiveness patterns, it cannot sufficiently explain or guide the development of new core technologies. Neither can it guide catching-up processes of technologically weak countries which are not characterised by previous strong path dependencies. The weak path dependencies in these countries and the configuration of their technology and innovation subsystems indicate that the potential spectrum of new successful specializations is not easily predictable. The policy implication is that risks cut both ways and characterise both types of policies: policies targeting ambitious projects for which capabilities and supportive conditions are insufficient as well as policies which don't facilitate specialization along specific new technologies, precisely in the belief that the external conditions make such a strategy risky.

What is central in this debate is that the two policy choices (concentration vs. decentralisation) are a theoretical distinction and that in reality the two approaches are not substitutes but complementary. Policy should remain flexible enough to deal with different realities and targets. The implication of such an approach means that the following options should remain open:

a) For technologically advanced countries, regions, areas and/or clusters:
   A concentration of resources in the aim to accelerate or support projects with relatively low probabilities of failure can complement horizontal policies, widening the opportunities for a broader spectrum of technological activities.

In this respect, two different situations have to be distinguished: a) the typical case of enhancement of activities, which represent the prevailing technological ecology of the country, and b) the technological targets with high potential social value (e.g. alternative energies, climate change, ecology-friendly production). Both these situations provide a rationale for more focused policies, although for two different reasons: In the first case, because the risk is low, and in the second, because the risk from failing to develop answers to these urgent problems has particularly harmful consequences.

b) For countries, regions, and areas belonging to the weak technology clubs, and characterized by less structured and developed innovation ecologies, policy should avoid to concentrate on projects, for which the overall conditions of success are weak. In particular:

- A rather horizontal policy allowing the country to exploit potential capabilities in directions which cannot be easily foreseen should have a greater importance,

- Concentrated efforts could favor projects and initiatives on a very selective basis, provided the expected benefits can be significant and the cost of failure remains limited.

From an E.U. perspective, strategic choices regarding frontier technologies or technologies targeting global risks should avoid to restrain followers from investing and developing capabilities in new for these countries technology areas. The question is what kind of investment capabilities will be chosen. Technological evolutions and applications are non-deterministic and even what appears as a duplication very often generates diversity and quite distinctive capabilities and/or new opportunities. The probabilities of success often depend on the capabilities of the actors and their innovation systems to discover, or even to construct, and exploit new opportunities. In other words, although targeted policies can be appropriate in a positive sense (e.g. to support the acceleration of technological advancements), they can have adverse effects if their consequence is to raise barriers, which can exclude actors, to limit windows of opportunities, the building up of new capabilities or the development of specializations of the followers in promising technology areas.

In view of these complexities, the question is which risk is higher: The risk of decisions preventing the development of specific specializations in the belief that they cannot lead to success or the risk of a plural approach opening windows of opportunities for a broader scope of specializations? Both approaches can succeed or fail and the answer depends on the very specific conditions. What can be said is that firstly, history of technology is full of examples in which technological discontinuities disrupted periods of technological stability and where neither the nature, nor the outcome of technologies were obvious ex ante, and, secondly, “markets can malfunction both when governments interfere too much, and when they interfere too little”[21] or wrongly. The issue is if, under these conditions, particular factors can be identified, which will facilitate the decisions about what should be ‘good at specializing’.

[21] D. Rodrik, Industrial policy for the twenty-first century (UNIDO, 2004).

6.5. Three different strategies

Different goals require different technology- and innovation-related specialization strategies. Three main strategies are distinguished[22]:

i) Strategies for technological leadership (strategies aiming at the frontier),
ii) Preventive strategies to face global risks,
iii) Catching-up strategies for (fast or slow) followers,

The implementation of all these three types of strategies can take a more targeted (pro-active) or a more neutral form. In particular, strategies to enhance specialization in emerging technological fields (cases i and ii), raise the dilemma between selection and non-selection in the policy-making process. It can be argued, that the goal to aim at the frontier and to address global challenges seems to favor a policy mix with more pronounced targeted approaches, while catching-up strategies call for rather more horizontal policy mixes. However, it would be misleading to consider specialization policies in absolute and/or dichotomic terms. In fact, even neutral policies comprise selections. What determines the success is the pragmatic mix between active and neutral approaches and the interactions between policy and its environment. Besides, the more technologically advanced the environment is, the more these strategies coexist within the same national space, as they serve to parallel goals of the same actor.

In addition to the production of technology, specialization policies should give emphasis also to diffusion aspects, which often are underrated. In the presence of weak trickle-down mechanisms, new technologies and knowledge will have a limited success in leveraging new specialization, competitiveness and growth. Diffusion of technologies, even if for different reasons, is crucial for both, convergence strategies and strategies aiming at the frontier.

6.5.1. Strategies aiming at the frontier

The rationale:

- Early specialization in emerging technological and the related productive areas leads to significant benefits both of economic and non-economic nature,
- Frontier technologies develop over many decades and historical experience shows that rarely, if ever, such technologies could develop without strong public support mechanisms,
- Risk-averting policies leading to latecomer positions in core technologies have often adverse implications in terms of growth, employment and competitiveness, which last for long, are difficult to reverse and affect economic and social performance.

The dilemma: Specialization strategies (especially in the framework of the Lisbon and the ERA policies) aiming at the frontier inavoidably raise a selection dilemma: which areas to enhance? Neither the Lisbon strategy nor the ERA project themselves have an explicit and

[22] Different and more detailed classifications are possible, such as strategies aiming at the preservation of existing specialization and/or prolonging product cycles, upgrading strategies, diffusion of technologies and innovations into new production areas.

specifically predefined content with regard to sectoral specialization, to areas of gravity or research objectives. The lack of an explicit specification of such priorities is not to confuse with a vacuum. The areas of gravity are implicitly outlined. Since the objective is to make of the E.U. 'the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion..', this by definition implies the need for the E.U. to develop capabilities on those (existing and/or emerging) scientific and technological trajectories, the dynamics of which drives forward economic growth and welfare in the present era. In this sense, the various high tech (and, selectively, even medium to high tech) areas occupy a central place in the implementation of the Lisbon and ERA goals. In fact, various thematic areas and other initiatives constitute significant priorities of the Framework Program or of the E.U.'s broader research and technology policy.

In other words, in order to meet the ERA and the revised Lisbon goals, research, technology and innovation policies have to target both the strengthening of existing technology and industrial structures (depending on their maturity, perspectives and other features) and the facilitation of deeper technical changes. Experience has showed that being a latecomer in core technologies can have serious implications which last for long, are difficult to reverse and affect economic and social performance. In the example of ICT technologies it became apparent, that followers don't succeed in avoiding productivity and competitiveness gaps as against leaders. Foremost, technological leaders, because of their leadership, are facilitated to expand into new science and technology fields and create conditions for reiterating such processes in further emerging science and technology areas.

Basically, many frontier technologies are continuously developed and transformed. Depending on the size and the capabilities, who will gain early enough strong positions in the evolving technological and production areas will be also capable to draw significant benefits both of economic and non-economic nature. Obviously, in the case of emerging technologies market signals are not yet strong to guide policy-making and risks of failure are higher. On the other hand, core technologies take many decades to be developed and the history of technological evolutions shows that:

- Rarely, if ever, core technologies have been developed without sufficient public supportive mechanisms,
- During these long periods multiple interactions between technological change and public policies are to be seen, which cannot be classified within one discernible pattern,
- Often public policies alternate between pro-active and reactive forms according to the specific evolutions and needs,
- In this interaction, even reactive policies can under certain conditions have also a pro-active nature.

The risks: Technology and innovation policies along these directions imply different risks. Policies aiming at frontier technologies because of weak path-dependencies face increased risks. The high uncertainties for private actors in such situations can make intervention appropriate, but not necessarily less risky.

The options: To deal with such risks, policy could be structured along three broad axes:

a) To target 'winning situations', by leveraging the success of clusters consisting of market players in particular technological, knowledge and specialization areas, based on market-led pre-selection, the evolving market evidence and in cooperation to market agents. What matters is to spark and to underpin a self-sustained cumulative development of new specializations and/or to assure a critical mass of capable market agents. A policy linking selectivity to targeting is very different from policies aiming at 'picking the winners'. The more significant differences are that[23]:

- Targeting is based on market evidence, on market-led pre-selection and existence of capable market forces and aims in leveraging the success of market players in particular areas,

- Government interventions in crucial transition points can have a significant impact on the effectiveness of technology and innovation activities,

- Targeting takes place in cooperation to market agents,

- It may be important to assure a critical mass of capable market agents.

  In view of these aspects, policy can favor the enhancement of broader 'winning situations', whereby the target is not to identify with individual firms or products, but with technological activities, technological areas or clusters of knowledge and specialization.

b) To broaden the policy spectrum by "evolutionary targeting", in the sense e.g. to assure a critical mass of capable market agents, to target the emergence or to leverage the success of new multiagent structures (or clusters) in particular areas. Evolutionary targeting "operates by enhancing market-led variety and pre-selection through horizontal policies, and accelerating market-led selection and development processes through coordination activities, targeted incentives, institutional changes and other policies"[24].

c) To combine a) and b) with smart policy initiatives and specializations[25]. 'Smart specialization' indicates a successful fine-tuning of policies envisaging the creation of competitive productive units, clusters and/or regions. It implies some kind of intervention, and, hence, some explicit or implicit targets coupled to some form of intended concentration of resources.

The concept of smart specialization (and in general smart policies) is attractive but has various practical difficulties. It assumes that we have the criteria to judge which specialization is smart and which not, and, consequently, which targets are smart. Smart policies can be acknowledged as such only after their success becomes visible, that is ex post.

It is very difficult to forecast the Darwinism of the markets during the stages from research to innovation or the combined outcome of market and policy processes. Policies can fail in a short period but be successful, and, hence, smart, over a longer period. Policies might fail

[23] G. Avnimelech, M. Teubal (2008), Evolutionary targeting, J. Evolutionary Economics, p.160ff.
[24] Ibid., p. 152ff., 160ff.
[25] D. Foray, 'Les nouveaux centres mondiaux dans le domaine de la recherche et de l' innovation: vers une economie de la specialisation intelligente (FutuRIS, 2008)' and 'Understanding "smart specialization" (July 2008)'.

because of bad implementation, although specific specializations might be smart and achievable through more efficient policies. Has smart to be defined in terms of technology excellence, of market success, of follower's strategy? On the other hand, in fact, there is an accumulated knowledge on the characteristics of smart and successful specialization policies. In reality, policy design has to strike a balance between the extremes: political voluntarism and agnostic approaches. The question is how to define the specifications of the needed 'smart specializations' in the framework of a particularly blurred research and technology landscape.

6.5.2. Preventive strategies to face global risks:

In this phase societies are faced with the need to develop technologies for dealing with qualitatively new global risks (climate change, energy, environmental issues), which enter more and more in the world agenda[26]. The recent crisis accelerated this process. What is at stake today for leading actors differs from the race to create new knowledge as an engine for growth. It transcends the issue of national or European convergence to the USA or the enhancement of technological capabilities and new knowledge for achieving higher standards of living. In the past, the leaders in new core technologies could achieve higher standards of living, create conditions of a more dynamic evolution, draw benefits in terms of political power, influence and welfare, and, depending on the policy values, enhance the social state.

In the present phase the development of technological capabilities to face the global risks associated to the climatic change, environment and energy, and their broader implications on health, food, water and other aspects (massive migration, conflicts) is a qualitative new issue. The risks associated to slow progress on what can be regarded as critical technologies are of a more generic nature, implying a potential deterioration of economic and social situations nationwide, E.U.-wide and even worldwide. Some particular technological fields are today of such an important priority that a failure has high social costs at all levels (E.U., national, regional eventually also global).

Briefly, because of the high social priority of some knowledge areas, pro-active (targeted) R&D specialization policies in these fields are not simply an economic, but also a significant social priority. In such cases we are faced with a kind of *public goods*, which require a policy response dealing with externalities, which the market alone is not able to offer. The key issue is the need for solutions within predetermined time limits, if social costs have to be kept within an acceptable range.

A difficulty is that in the case of expected global risks it is inherently difficult to have an ex ante measure of what is success or failure. In the case of new technologies able to meet global risks the measurement of potential benefits and costs differs profoundly from the

[26] "European research policy should be deeply rooted in European society. Besides the pursuit of scientific excellence, European research should support knowledge advancement and dissemination and underpin policies for sustainable development in fields of major public concern such as health, energy and climate change" (ERA Green Paper).

conventional micro-economic logic. How to measure future costs and benefits from the development or not of alternative energy technologies? How to compare the cost and benefits of action and inaction, especially when the present technological options are restricted? Nevertheless, policies of selection and risk taking are necessary. Otherwise, 'non-selection' will also have risks and costs. The risk of inaction or of a delay to support the advancement of critical technologies could be larger than the cost of action. It could be significant in terms of growth, employment, competitiveness, market positions and environmental degradation. It could have adverse economic and social effects. Inversely, a successful management of these policy issues can result in significant benefits in economic, social and even political terms (e.g. stability).

In such a blurred landscape, a significant difference between more targeted and neutral specialization strategies might be that in the case of the latter, broader systemic failures to meet timely major risks, rather than being a probability can become a certainty. The issue is that additional criteria for decision making are necessary, but of which kind?

6.5.3. The catching-up and the convergence issue:

a) The rationale

Upgrading and catching-up policies are important, mainly for followers, but also for leading players in technology areas in which other countries or firms are leading. Historically, a significant part of technological progress occurred through technology transfer, technology diffusion and imitation. However, the race towards creating 'differences' as an engine for specialization and growth implies shifting away from simple imitation of successful specializations to differentiated and/or new forms of knowledge combinations. In fact, simple imitation strategies in the long run cannot be first best solutions for any follower. Instead, the most successful players have been those who could create an own path, based on their accumulated knowledge, productive and innovative capabilities.

b) Policy issues and the distinction between simple and smart imitation or adaptation strategy and the role of internal capabilities

In contrast to the advanced technology systems, the absence of co-evolutionary processes between technologies, institutions, business activities and public policies in technologically weaker players increases the policy risks and uncertainties, in particular in the case of more targeted interventions. In technologically leading countries there are many signals on capabilities, achievements, progress in various areas, emerging knowledge, patents, innovation failures and successes and a broad network of relations between the firm sector and the government, which provides policy with specific information and certain degrees of predictability and probability. Government decisions can be taken in cooperation with research and technology active firms and research organizations. As a consequence, the outcomes of 'evolutionary targeting' or 'smart interventions' in this group of countries are less risky. Inversely, in weaker players the risks and uncertainties are higher and make targeted interventions more uncertain.

Notwithstanding these uncertainties, the cause-effect relationship between specialization and technological mastery in weak technology systems is reciprocal. For technology specialization to be transformed into competitive advantages there is also need of a sufficient level of expertise over the broader scope of the related technological base. Even more, such policies can be quite supportive for technological activities and/or the creation of specializations of a ‘lower order’ (technology transfer, adaptation, imitation), sometimes with very successful implications. As a result, the very creation of investment and production capabilities, associated with technology diffusion, requires some forms of technology-related capabilities in order to absorb, assimilate and exploit commercially and competitively knowledge related to the specific investment and production. Hence, while the weak market signals increase the unpredictability of where it could be good to specialize, they also increase the risk of preventive or deterrent decisions concerning the areas where capabilities should better be created. In fact, policies regarding followers should be flexible, gradual and avoid the risk to prevent or to deter efforts to build capabilities and specializations in promising fields.

However, the study of imitation strategies in the catching-up process does not lead to unqualified conclusions. Imitation is not following a ‘linear logic’, which leads to a reproduction of what has been discovered elsewhere. Although it concerns technology fields in which early entrants have strong positions, it often generates differentiated outcomes (in terms of quality, functionality, adaptation, incremental improvements). It can also succeed to address groups of users with locally differentiated needs, and gain market position because of lower prices and qualitatively adjusted products. The successful development of software industry in India is an example of how specialization can develop by producing differentiated products addressed to a highly differentiated demand pattern. Even more, it shows, that because technology and knowledge are combined with local labor and/or capital and other inputs, the competitive position of the follower is determined not only by the use of that knowledge, but also by the wider combination and mastery of this knowledge with these other inputs, their prices and the productivity relationships. The examples indicate that one should clearly distinguish between specializations based on capabilities to create new knowledge, to absorb new knowledge or to succeed to apply and/or exploit such knowledge in innovative ways independently of its origin.

In fact, the examples of countries achieving successful specializations by targeting specific technology-related niches are notable (e.g. Taiwan in orchid industry, India for software, Pakistan for soccer balls, Colombia for cut flowers)[27]. In many cases smart choices have led to successful specializations with significant benefits for the players. Moreover, during these processes new expertise and knowledge have been created, which subsequently enhanced further the capabilities and the technological transformation of these countries. On the other side, various such specialization strategies were not always genuinely innovative. Often, they have been the outcome of successful adoption strategies of existing specializations, showing, however, how important factors technology diffusion and adjustment are in the catching-up process. Through different innovative combinations new competitive advantages have been achieved, the components of which were not only the knowledge inputs, but also the availability and the prices of other available and necessary inputs (e.g. labor cost, infrastructure investments, incentives, supportive institutions, capturing of externalities, policy-making).

It can be argued, that in catching-up countries the development of facilities and competences in specific fields in which a country has significant weaknesses can be regarded as a waste of resources, since at a first glance they hardly can lead to competitive specializations. Weak actors and late entrants have a reduced scope with regard to leaders, at least in initial phases. However, this is half of the truth and concerns mainly the attempt

[27] D. Rodrik, (2004), Industrial policy for the twenty-first century (UNIDO).

to compete at the level of scientific and very basic technological discoveries. The other half is that the building of capabilities in new technological areas is not to be regarded in relation only to the early phases of radical and/or significant technical changes. The early phases at a later stage are followed by incremental technical changes, different applications, innovative combinations of existing knowledge or the generation of new specialization niches within the dominant technology fields. In all such examples it is quite rational for followers to create capabilities related to these technologies. As technological change evolves, capabilities of the followers become a moving target, since they have to be continuously improved even for keeping their relative position stable.

Notwithstanding such successful examples, horizontal policies appear, however, to be a less risky approach for technologically weaker systems. They generate decentralized selection mechanisms, learning processes and a diversification of specialization patterns, while they also facilitate innovative forms of combinations between technological knowledge and local factor capabilities.

7. **A lesson from the financial crisis: The importance of regulating risky innovation-based specializations**

The present financial crisis, and particularly the mechanisms underlying its origins made more explicit an additional policy dimension with regard to technological specialization policies. They showed that besides the question of 'what policies for good specialization, innovation-based specializations have to be judged not only on their growth-generating potential, but also on their risks. This implies the need to complement short-term criteria for policy-making with medium- or long-term considerations.

At the origin of this crisis one can find the significant role of financial innovations, as expressed in the new financial products, including the derivatives or the securitization of loans and the spread of these titles and their associated risk worldwide.

Governmental practices followed the typical device to enhance promising innovations: they proceeded to significant institutional changes facilitating the expansion of these products, even more since they ensured a particular impetus to growth. New, more lax, regulations on supervision, operational functions, financial leverage practices were introduced, accepted and adjusted to the perceived new growth opportunities. As known, the result was the creation of an innovation-induced growth mechanism, which after reaching its limits, caused an unprecedented recession, bankruptcies and unemployment, with significant destabilizing impact on large parts of the world economy.

Taking into account the fact that the most serious destabilizing phenomena during the last twenty years (starting with the nationally based Tequilla crisis in 1995) were of financial nature, a lesson to be drawn is that what matters is not only where and in what to specialize or how the creation of temporarily smart 'differences' can enhance innovative specialization patterns. In addition, the issue is how governments can frame innovative specializations and control their applications, in the aim to prevent serious negative effects (social, economic, environmental or other)[28]. More precisely, the issue is that policies on good specialization

[28] A different, albeit related, example is the institutional regulations introduced in the case of genetic cloning.

should comprise the capability to perceive, prevent and protect from bad or risky specializations.

8. What choices and how to deal with risks?

Frontier research is not a question of percentage spending to GDP but of smart goals and policies as well as of appropriate absolute amounts of financial and human resources. Evidence shows that voluntaristic top-down approaches have often failed, but that neutral policies often have also a failure cost, except that this takes less transparent forms. The success of both, target-related and neutral strategies depends largely on the articulation of the policy mix and the definition of the objectives.

Faced with different asymmetries of information, risks and opportunities, policy-making can be addressed as a risk management issue and could draw from the concept of *'portfolio management'*, adjusted to technology and innovation policies. Portfolio management approaches favor variety and selection mechanisms, can reduce risks and assess the multiple research and technology objectives on the basis of such criteria as financial cost, probabilities of success, externalities and/or social costs and benefits. An interesting distinction in this respect is between related and unrelated varieties, because it reflects the very diverse realities between technological leaders and followers and the factors determining the rationality of different kinds of policy[29].

Even if technology and innovation activities by their nature are high risk activities, firms are expected to follow Schumpeterian behavior and intensify research and innovation. In a Schumpeterian-driven economy the State cannot ignore the need to select specific goals and means and to take also its risks in this process. The selection by the market only may fail by reasons like externalities, public good characteristics etc. and the selection by policies may fail as well. Hence, for public technology and innovation programs a portfolio management may provide a useful instrument through which risks will be spread and minimized, especially when a close cooperation between politics and the business sector is secured.

The main question still is how to shape targets and choices, which can better reflect the politically accepted balance of policies, social risks and benefits. In view of the mentioned three major E.U. challenges the question is if and what new policy concepts have to enrich or to enhance the existing policy-making process, how policy could better succeed in organizing a flexible and diversified framework and implementing specialisation targets[30]. Our analysis implies also that in the framework of the ERA the support of high tech clusters is a necessary but not sufficient condition for successful policies. What is essential is to

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[29] K. Frenken, F. van Oort, T. Verburg (2007), Related variety, unrelated variety and regional economic growth, Regional Studies, 41, 5, 685-697.

[30] Pro-active policies at the EU (and national) level can aim at a 'research friendly ecology' (Georghiou, 2007), and be selectively combined with a 'cluster-specific environment'.

shape governance structures which can conceive timely and effectively the necessary R&D and technological policies[31]. Success is codetermined by a range of additional elements:

- An appropriate coordination at European level of public organizations, business firms and research communities, each of which has different interests, priorities, or strategies (e.g. on the appropriation of new knowledge) and functions,
- The design of priorities on selected areas and a package of policies to support the research activities of firms and organizations and a close cooperation with the business sector and the scientific community in detecting needs, capabilities, technological trends, key discoveries, possible advancements,
- Policies promoting existing or emerging technologies, instead to proceed on a voluntaristic base have to rely on the signals of the (research, innovation, product) market,
- For the evaluation of success, the selection of priorities as well as other policy strategies has to consider externalities -positive as well as negative ones-, like climate change, energy supply, environment issues. Within the concept of portfolio management, the effects of these externalities have explicitly to be taken into account,
- The broadening of the criteria on the basis of which the success of research and technology specialization policies can be assessed, especially with regard to the coherence, the efficiency, the long-term commitment of these policies as well as the time framework within which policies have to be implemented,
- The enhancement of variety creation and the selection and support of differentiation elements vis-a-vis competitors, and
- The capability to design and implement effectively appropriate policies and governance of these policies (i.e. the national innovative capacity) in a long-term period, since the effectiveness of policies often depends on:

    a) the way they can meet successfully the above conditions,
    b) the complementarities with other policies,
    c) the broader economic environment,
    d) the supportive activities, and
    e) the social capabilities to adjust and to exploit opportunities.

The problems are different for big and smaller countries. Big countries benefit from the advantage to have more large areas where research can be distributed. In contrast, smaller countries have fewer choices to differentiate their technology and innovation activities. Consequently, they are characterized by a more concentrated and more risky pattern of technology and innovation choices. Big countries can follow a differentiated policy with regard to their different regions. Even a regional polarization -in terms of research, knowledge, clusters and/or sectors- has different implications for bigger and smaller

[31] See for example the principles of 'governance and trust' proposed by R. Marimon, M. de Grace Carvalho (2008), p. 9ff.

innovation systems. Besides, nothing ensures a trickle-down of the benefits from technologically strong to weaker regions, especially between different countries.

The element of cumulativeness with regard to scientific knowledge influences positively also the capabilities to enter new areas of knowledge, even if this knowledge is discontinuous and revolutionary in some respects[32]. Often, new elements in new science fields are interconnected with old elements, which are transformed, incorporated and combined with the new elements and lead to new forms of knowledge. From the policy point of view, this implies that accumulated knowledge facilitates the transition to new research and technology areas. Societies with weaker capabilities will not be able to achieve such transitions. Gaps of such a kind cannot be closed without active policies, and, in particular, RTD policies. In the present era of technological race as a source of competitive specialization advantages, RTD coupled with appropriate structural policies should have a distinguished place also in cohesion strategies. Consequently, technological specialization in the ERA has to be considered in the framework of a balanced approach, conciliating technological advancement and cohesion.

The issues of cohesion and intra-E.U. convergence are a different but crucial aspect of R&D and technology specialization strategies. Regarding specialization in the framework of the ERA and from the cohesion point of view, the issue has not yet been answered sufficiently. R&D and technological specialization, if successful, drives industrial specialization and industrial specialization drives competitiveness, growth, incomes and standards of living. Even if reality often differs from such a linearity, differential growth capabilities lead to divergences and raise the question of possible trade-offs. The Lisbon goals and the closing of the gap between the E.U. and the U.S. in the crucial areas of research and technology performance explicitly or implicitly constitute a major objective for the EU. The same considerations, however, have to prevail regarding the internal E.U. gap.

The ERA can facilitate the development of a range of high-tech milieus with internal and external interactions, linkages with business partners, public research organizations and communities of joint research and technology targets. Such poles of excellence could support the promotion of emerging new technologies with crucial economic and/or social implications. The development of such high tech milieus is justified from the critical mass of resources (financial and human, physical and soft infrastructures) which are needed but cannot be provided in the framework of existing policies at lower levels of governance. In such a perspective the ERA can enhance research and technological change enabling both the leveraging of continuous change, adaptation, and competitive strengthening of industrial structures as well as the unfolding of emerging new technology fields.

[32] Zucker L.G., Darby M.R., Furner J., Liu R.C., Ma H., (2007), Minerva unbound: Knowledge stocks, knowledge flows and new knowledge production, Research Policy, 36., 850-863, Furman J.L., Porter M.E., Stern S., (2002), The determinants of national innovative capacity, Research Policy, 31., 899-933.

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