European Commission

Co-development

of Science and Technology at a National Level

and the Use of European Funding Instruments

Innovation Union

Competitiveness papers

Issue 2013/4

Research and Innovation

EUROPEAN COMMISSION

Directorate-General for Research and Innovation
Directorate C — Research and Innovation
Unit C.6 — Economic analysis and indicators

E–mail: rtd-innovation-papers-studies@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu

Contact: Carmen Marcus

European Commission
B-1049 Brussels

EUROPEAN COMMISSION

Co-development of Science and Technology at a National Level and the Use of European Funding Instruments

Innovation Union
Competitiveness papers
Issue 2013/4

Authors of the study
Carmen Marcus, Johan Stierna and Cristina Moise
European Commission, DG Research and Innovation
Unit C6. Economic Analysis and Indicators

Directorate–General for Research and Innovation
2013

LEGAL NOTICE

More information on the European Union is available on the Internet (http://europa.eu).

Cataloguing data can be found at the end of this publication.

Luxembourg: Publications Office of the European Union, 2013

ISBN 978-92-79-31234-2
doi:10.2777/30492

TABLE OF CONTENTS

FOREWORD

In 2009, the Economic Analysis Unit of DG Research and Innovation of the European Commission launched a series of studies aimed at developing a system capable of sustainable monitoring of knowledge and R&D flow from research to technology and to the market, given the increasing focus on measuring the impact of research activities on the economy. Two of these studies were focused on indicators and analysis of scientific publications of both public and private research actors, as well as patents & licensing activities of economic operators: '*Analysis and Regular Update of Bibliometrics Indicators*' carried out by Science Metrix (Canada): Éric Archambault, David Campbell, Isabelle Labrosse and Grégoire Côté; and '*Knowledge and R&D exploitation flows, assessed by patent and licensing data*' performed by a consortium consisting of: KU Leuven (coordinator): Bart Van Looy, Julie Callaert and Caro Vereyen; Bocconi University: Stefano Breschi and Gianluca Tarasconi; and Technopolis Consulting Group Vienna: Alfred Radauer.

In order to better allow for the analysis of knowledge transfer from science to technology in a given field, a common denominator was needed for the various classifications of the fields of science and technology. Given that Framework Programmes represent a core business of DG Research and Innovation, it was natural to choose the thematic priorities of the 7th Framework Programme as the common denominator. Matching the science and technology classifications with FP7 thematic priorities was performed by two contractors, offering the possibility of further analysis of co-developments of science and technologies at a national level, as well as allowing the use of European funding instruments.

This is what the current article does. It essentially aims to show what the European countries' capabilities are in terms of science and technology, to what extent there is a co-development of scientific and technological fields of expertise at a country level, and to what extent these capabilities, separately or jointly, are reflected in the countries' participation in the 7th Framework Programme.

I hope that this analysis will constitute a useful tool for policy makers, for public and private research performers, as well as for technology-based private research performers and technology-based firms. It might indeed constitute an evidence base for R&I strategy making, for the development of smart specialisation strategies by countries, or for private decisions on investment in innovation or participation in cluster activities.

Pierre Vigier
Head of Unit: Economic analysis and indicators
Directorate-General for Research and Innovation
European Commission

INTRODUCTION

Excellent and enlightening research results are finding their way into international publication indexes, the most well-known worldwide being ISI Thomson and Scopus. In addition, the analysis of publications provides a secondary measure of quality through the number of citations of a given publication in top journals worldwide. In the case of patents, both applications and granted patents aimed at protecting the intellectual property of an invention beyond national borders are considered a valid measure of the quality of that given invention. Alongside performance, data on publications and patents can be used to construct specialisation indexes. When a country is specialised in both science and technology for a given domain (e.g. energy), as measured by publications and patents, it means that nationally produced science is more likely to be absorbed by industry, through technologies, for that particular domain.

On the one hand, this paper conceptualises the matching of science with technology and industry as part of the larger process of *economic rationalisation*. It compiles theoretical models and analysis to show that the co-development of S&T at a national level is a feature of well-performing innovation-driven countries. On the other hand, the paper also considers the transformative potential of a mismatch between science and technology-industry. Under certain circumstances, an excellent science base in a strategic field can be the embryo of structural change, transforming part of the established industries through the growth of new firms or sectors. This possibility is conceptualised as part of an *economic transformation*.

In both cases, the European Framework Programme (which is the main funding instrument for S&T at the European level) may have a leveraging effect. It offers the potential of further strengthening national performance and science-technology matching. At the same time, it provides critical mass and focuses European excellence on science and technology areas with a strong transformative potential going beyond the existing structure of industry to global social challenges and lead markets. The programme facilitates the creation of international networks among the best performers, while at the same time not excluding the catching-up European countries. From 2014, this role will be taken over by the Horizon 2020 programme.

Annex 1 of this article contains an empirical analysis of matching the dynamics of science and technology in EU countries over the last decade, divided into groups of countries with similar scientific and economic features. It also compares the national S&T capabilities with the level of country participation in the various thematic priorities of the European 7th Framework Programme. Annex 2 includes relevant background data allowing an analysis of each individual European country and sector.

1. Rationalisation versus transformation in the analysis of national S&T co-developments

1.1. Co-development of science, technology and industry

Knowledge and science acquire their full economic value when used (Porter, 1990). Economic evolution inside a given technology and industrial structure ('paradigm') is pushed by a process of rationalisation, a constant effort by firms and economic actors to allocate and reallocate existing resources to ensure their optimal economic impact (Schön, 2009). An industry segment is continuously upgraded to reach its competitive edge. Science is an important dimension in this rationalisation process, although it is important to bear in mind that science is not equally important in all industries (Malerba, 2002).

A recent paper affirms that over longer periods of time co-specialisation in science and industry at a national level occurs naturally in industries with a significant input of science and technology, even without a specific policy intervention. With the words of J.P. Murmann (2013): *'...the relative strength of a national industry which has a significant input of science or engineering knowledge is causally related to the strength of the relevant science or engineering discipline in the nation and vice versa. Over longer periods, a nation cannot remain weak in one domain and strong in the other. Both domains will either become both strong or both weak.'*

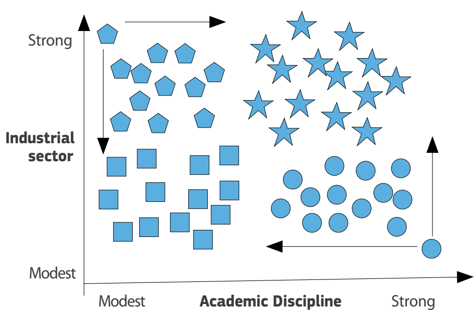
> *Research shows that, over longer periods of time, a country is likely to become either strong in both science and technology, or weak in both science and technology in industries that have a significant input of S&T*

Why would this happen? The author shows that there are many factors concurring with this result: when they have common interests in a certain domain, academics and business people will jointly lobby for a particular scientific field and a specific industrial sector. Researchers will engage in economic activities when there is a financial incentive for their research projects, and will prefer to start firms in areas that are close to their academic fields. Finally, students will choose to study academic disciplines in which they have a better chance of finding employment after graduation, and entrepreneurs will enter into sectors that promise higher profits.

According to this model, the intervention of the government aimed at strengthening S&T in specific sectors makes sense either in the case of strong science and modest industry, or in the case of strong industry and modest science. Section 2.3 will look more closely at possible types of policy intervention.

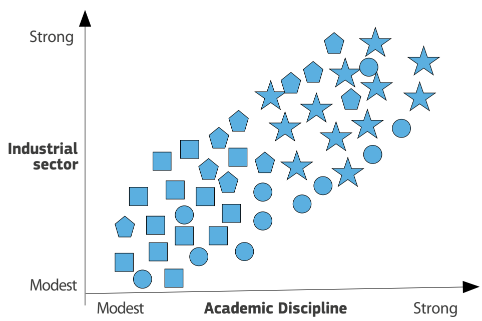
One way of verifying this model, as acknowledged by the same author, is to measure the S&T linkages in technologically developed industries through the use of *patent examiner citations of the scientific publications in patent applications*. This has been done in the context of a study financed under FP7[1], which came to the conclusion that technologically strong countries are empirically correlated with both high levels of scientific productivity and important science-technology relatedness, as measured by publications cited in patents.

Forces of unstable Academic-Industry complexes at a national level at Time T1



Source: Johann Peter Murmann — cited paper, p. 233

Co-development at a national level at Time T2

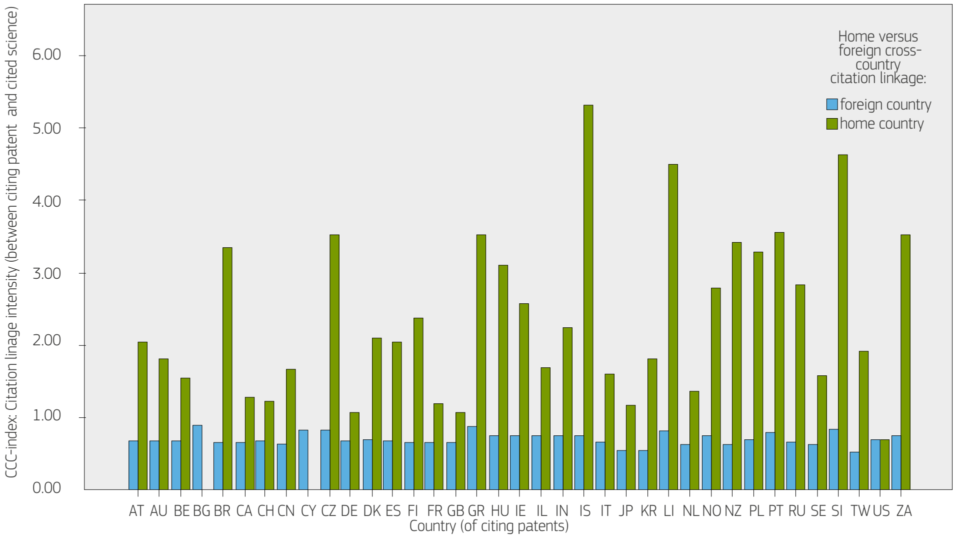


Source: Johann Peter Murmann — cited paper, p. 233

1 J. Callaert *et al.*, '*Patterns of Science-Technology Linkage*', 2013 (forthcoming).

When comparing in the figure below the within-country citation intensity to the average citation intensity with foreign countries for each citing country, the results show that technological development in a country appears to link primarily, although not exclusively, to the country's own national science base (see the general situation of green bars being higher than the blue bars). with a smaller science base of their own. Among them, there are countries that are already successful in attracting foreign direct investments (FDI) for high-tech and medium-tech based economic activities, but which do not yet have a sufficiently advanced science base able to support the transition from technology diffusion to technology creation (for

Comparison of within-country (home) citation intensity (green) to the average citation intensity with foreign countries (blue)



Source: J. Callaert *et al.*, *'Patterns of Science-Technology Linkage'*, (forthcoming)
Notes: Patent data: *Aggregation USPTO, EPO and PCT patents*, application years 2000–2009; Scientific data: Web of Science (1991–2011)

The figure reveals country differences in the extent of the home advantage. For some countries, the home effect is much less outspoken: they rely on both foreign science and home science. These are mainly technologically strong countries, such as the USA, France, the United Kingdom, Japan and Germany, with capacity to source knowledge globally. Nevertheless, further analysis[2] shows that whereas a broader geographical scope in citing science has positive effects on national technological performance, these leveraging effects are not decisive for countries with large scientific capabilities at home, for countries instance the Czech Republic or Poland. These would be the countries that, according to Porter, are in transition from the efficiency-driven to innovation-driven stage (see section 2.1) as opposed to those that are already at the stage of technology creation — already innovation-driven economies. There are also countries that still need to focus on attracting FDI for general purpose technologies in order to ensure the efficient functioning of the economy across all its sectors. These are efficiency-driven economies, with Romania and Bulgaria being typical examples of European countries (see section 2.1).

The co-development of science and technology at a national level appears to be a characteristic of technologically strong countries (or innovation-driven economies). The positive effect of co-development in S&T at a national level does not exclude the use of foreign science and technology for increasing the technological development of a country. However, research has shown that the leveraging effects of using foreign science for increasing technological activities at a national level are less decisive for countries with a strong home science base than for countries with smaller domestic scientific capabilities.

2 For a more detailed account of these analyses, see the same report *'Patterns of science-technology linkage'* (Callaert *et al.*, 2013, forthcoming).

1.2. The transformative potential of science and technology in times of crisis

There are limits to the rationalisation process inside a given techno-economic paradigm. A too linear match of science and industry may lead to technology lock-in and the subsequent decline of an industry. It may also lead to missed opportunities of growth responding to emerging social challenges and lead markets. Science may be shaped too strictly into the existing boundaries of an established industry, losing its potential for renewal through the convergence of science and technologies from different fields and sectors (see Malerba, 2002).

Whereas co-development of science with technologically-strong industries is often the result of a rationalisation effort aimed at ensuring the optimal economic impact of existing resources, the transformative potential of science and technology becomes more relevant in times of economic crises.

Empirical studies point to diminishing economic returns at the end of a rationalisation process. This may lead to an economic crisis in a long-term cyclical process. The study by Schön shows how the Swedish economy entered into economic crisis in the 1890s, 1930s and early 1970s, and how the economy recovered from these crises through a structural change adapting or creating a new techno-economic paradigm. The broad diffusion of transformative technologies, such as electricity in the 1890s, electronics in the 1930s and ICT in the 1970s, transformed the Swedish economy into a new rapid growth phase (Schön, 2009). Similar trends can be illustrated in other economies. Castells analyses the broad economic diffusion in the 1970s, showing the previous convergence of information and communication technologies as a structural response to falling productivity growth in the major world economies (see also Verspagen, 2000). The full economic utilisation of this new ICT paradigm resulted in a rapid growth of new firms and sectors. Subsequently, a rationalisation process took over, with larger firms changing their organisational model into transnational networks (Castells, 2000). In his interpretation of the current economic crisis, Stiglitz points at a similar structural cause, where productivity growth from the ICT roll-out slowed down after the ICT stock market bubble burst in 2001. According to Stiglitz, from that moment productivity growth was maintained artificially through lending into the housing market, largely based on capital from Asia being invested in the USA and Europe. When the housing bubble burst in 2007, the structural productivity deficit became apparent (Stiglitz, 2010). In line with the previous historical analysis, there is a hypothesis that the Western world is currently facing the challenge of a required transformation of its prevailing techno-economic paradigm to recover real economic growth.

The growth of excellent science not forcefully linked with existing industry may, under certain conditions, generate transformative technologies. Policies addressing societal challenges, challenge-driven innovation and focus on lead markets are promising avenues for such a transformation. The critical mass and the strategic and global nature of the EU Framework Programme, as well as that of its successor Horizon 2020, have the potential to support innovation-driven countries in their transformative science and technology efforts in converging technologies. In addition, under the concept of smart specialisation, European policy is mobilising EU structural funds towards research and innovation-driven specialisation, or diversification. This policy can lead to both matching and transformation, depending on policy strategies and the innovation strengths of various regions.[3]

1.3. External factors that influence the co-development of science and technologically-strong industries

So far the text of the paper has run through existing arguments for various types of co-development between science and industry, both in times of economic growth (rationalisation) and as growth-enhancing responses in times of crisis (transformation). However, it must be remembered that a certain causality of science and technology co-developments, as presented above, is not inexorable. The overall interaction between science, technology and economic development is also influenced by factors that are external to the economy and to the R&I system as such, and which are no less important. These may be large political transformations and long-term cultural changes, to name but a few.

3 The smart specialisation concept was originally developed in the context of the Knowledge for Growth Group of the Directorate-General for Research and Innovation of the European Commission (Forey, David, Hall, 2009). Adopting and further developing the concept, the Directorate-General for Regional Policy of the European Commission asked Member States for developing strategies for smart specialisation as an ex-ante conditionality for the next programming period of structural funds (2014–20).

Large political transformations will trigger major changes in research and innovation systems. The fall of the communist bloc, for instance, created the need to drastically reshape the research environment of the countries concerned. Many of these countries are still in the process of reshuffling their institutional structures and specialisations as a result of the dramatic change in the orientation of the markets from East to West, and of people's mind-set from communism to democracy. The changes will occur sooner or later according to the specific conditions of different countries. Some small countries, such as Estonia, where the people have a strong entrepreneurial spirit, have been able to transform their R&I institutional structures earlier than certain larger countries.

Beside a certain dynamics of science and technology co-development, characterised by rationalisation efforts in times of economic growth and by spurring transformative potential in times of economic crisis, there are many other factors that influence the overall interaction between science, technology and economic development at a given moment in time.

In addition, ***acquired knowledge*** tends to be preserved over longer periods of time, even if this is not always directly seen in figures. The aeronautics industry in Poland, after a dramatic fall in the aftermath of the political events of the 1990s, succeeded in being reinvigorated in a process that started bottom-up from researchers and businesses, becoming today the most successful economic cluster in Poland. The food and agriculture sector in Romania might follow the same type of transformation. After a dramatic fall during the last 20 years, the state of science in the fields of food, agriculture and biotechnologies is slowly starting to revive, by using the immense natural potential of the agricultural sector in that country.

Last but not least, ***cultural factors*** will make a crucial difference in the research and innovation related activities of an economy. For instance, there is a net difference between Malta, having had its university in place for more than three centuries, and Cyprus and Luxembourg with rather young university systems, of about one century old. And, again, the present ***policy decisions*** will shape future R&I and economic transformations. For instance, whereas Cyprus prefers to import technology from abroad, which can be considered a perfectly valid choice for a small-size economy, Luxembourg is striving more to develop its own R&I capacities at home.

2. Dynamics in analysing the co-development of science and technology at a national level

2.1. Different stages of economic development of countries

When looking at the dynamics of S&T specialisation at a national level, the analysis has to take into consideration the fact that different countries are at different stages of economic development. Porter (1990) classifies countries into three categories: The first category is *innovation-driven economies* — knowledge-based, high-income and technology-generating, which innovate in at least some sectors on the global technological frontier. *Efficiency-driven economies* are middle-income economies that aim to import technology through foreign direct investments (FDI), joint ventures and outsourcing arrangements helping to integrate the national economy into international production systems. The third category is low-income economies or *factor-driven economies,* where economic growth is determined by the mobilisation of primary factors of production: land, primary commodities and unskilled labour.

According to the 2012–13 Global Competitiveness Report (World Economic Forum, 2012),[4] most EU Member States are already innovation-driven economies, or in transition towards the innovation-driven stage (including some Eastern European countries such as Croatia, Estonia, Hungary, Latvia, Lithuania and Poland). A couple of them remain for the moment efficiency-driven economies (Romania and Bulgaria). The importance given to innovation by the EU Member States, and overall the orientation towards reaching a state of knowledge-based economies, is fully supported by EU policy: research and innovation are placed at the heart of the Europe 2020 strategy for growth and jobs, and represent important priorities at a national level.

Porter further suggests that the focus of countries should be different according to their stage of development: countries in the efficiency-driven stage must speed up the process of technology investment and diffusion in order to increase the overall efficiency of the economy, in part by attracting high-tech FDI;

4 http://reports.weforum.org/global-competitiveness-report-2012-2013

countries in transition towards the innovation-driven stage have to make an effort to pass from technological diffusion to technological innovation; and the most advanced countries would focus on maintaining competition in high-tech or global markets, avoiding any possible decline in competitive position.

The competitive advantage of a country depends in the end on the strengths and interaction of knowledge supply, home demand, firm strategies, competition and related industries, as well as their interaction, a systemic model that Porter called 'diamond'. For instance, Porter emphasised that advanced and sophisticated home demand is an important factor for raising the national competitive advantage of a country. If a country has a home demand determined by stringent national specific needs, it has more chances of becoming competitive internationally in the respective segment of the industry that has been developed to respond to those needs.[5] However, a sophisticated home demand only benefits national competitive advantage if it anticipates demand elsewhere, globally. Porter's theory, which includes the variable of home demand, stood at the basis of the European Commission developing the concept of *lead markets*.

Any analysis of countries and specific policy initiatives must take into consideration existing differences in terms of economic development and competitive advantage. Porter defines three categories of countries in this respect: innovation-driven economies, efficiency-driven economies and factor-driven economies.

On the basis of Porter's theory, it could be assumed that not all countries in Europe have the same potential for technological transformation in the sense described previously. It would require not only excellent and relevant science (part of the knowledge supply), but also a vigorous 'diamond' capable of mobilising an innovative idea out to the market in areas of global economic potential. In this context, the European Research Area and the Single Market act as facilitators of knowledge diffusion and absorption throughout the European economy, expanding the paradigm shift begun by innovation leaders.

2.2. Brief operationalisation of the smart specialisation concept

In addition to considering the differences between countries in terms of economic development, a dynamic view on science and technology co-development will also need to look at the potential of specialisation according to the comparative advantages of various sectors. An interesting operationalisation of the concept of smart specialisation at a regional level was done by World Bank experts in 2012.[6] A simple typology makes a distinction between three types of regions: regions with apparent comparative advantages (based on existing globally competitive industries); regions with latent comparative advantages (no substantial economic activity but natural resources or skills/R&D capacities); and regions with unknown comparative advantages (no visible industry or R&D or raw materials).

Extrapolating the World Bank analysis at the level of industrial sectors, we can distinguish among three types of situations:

★ **Economic sectors with apparent comparative advantages**, where globally competitive industries are already installed; another element to be taken into account in this case is whether the industries experience growth or decline, related to the sustainability of specialisation. In this case, a better match between science and technologies in the sector could help the industry to either maintain a competitive edge in the sector or regain competitive advantage by investing in R&D and innovation.

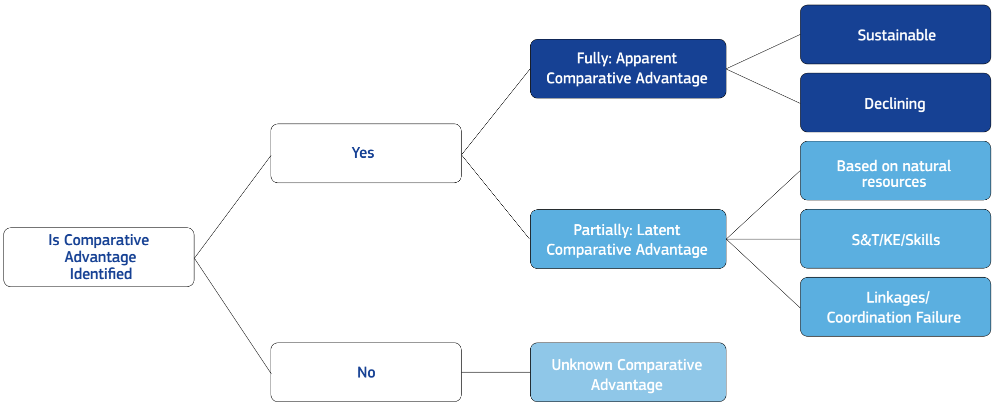
5 Porter gives the example of Sweden becoming a leader in high voltage distribution equipment, used for transporting high voltage over long distances, due to a large relative demand in this segment linked to the remoteness of Sweden's energy-intensive steel and paper industries from the original energy source.

6 The World Bank, 'Research and Innovation for Smart Specialisation Strategy: Concept, Implementation Challenges and Implications', Draft 25 June 2012, prepared as a background note for the Workshop: 'Smart Investment for Smart Specialisation: A Regional Practitioners' Exchange' — Warsaw, Poland 27–28 June 2012.

★ **Economic sectors with latent comparative advantages**, where there is no substantial economic activity but clear potential in terms of either raw materials and natural resources or capabilities such as skills and R&D specialisation in corresponding scientific fields. This is a situation with transformative potential under the condition that the 'diamond' is vigorous. Policies oriented towards entrepreneurship, skills formation, public procurement (or broadly framework conditions for private R&I) and supply-demand related lead markets have the potential to unleash structural change.

★ **Sectors with unknown comparative advantages**, where there is neither visible industry nor natural resources, nor R&D nor traditional skills. In this case, more general, horizontal measures are useful, such as comprehensive investment in knowledge, improving the overall business environment, developing entrepreneurial skills, promoting firm entry and start-ups and allowing firm exit.

Understanding economic specialisation



Source: The World Bank, 'Research and Innovation for Smart Specialisation Strategy: Concept, Implementation Challenges and Implications', p. 16

2.3. Four types of S&T co-developments, to conclude with

If we were to synthesise the whole conceptual framework presented so far, with a view to using it in further empirical analysis, we can distinguish four different categories of science-technology co-development, as presented in the figure below.

Whereas a given country can face each of the four situations in the case of specific domains of science and technology, an overall perspective will unveil situations that are rather characteristic of catching-up countries when looking at the left-hand side of the graph, and of more advanced innovation-driven countries when observing the right-hand side. Similarly, the upper part of the graph will relate to situations of the rationalisation of existing resources to achieve a greater economic impact building on the existing strong technological developments, whereas the lower part of the graph presents the potential for transformation processes starting from a low(er) level of technologies.

Typology of Science-Technology Co-development

Technological field \ Scientific field	Modest	Strong
Strong	**Modest science — Strong technology** *Rationalisation* Efficiency-driven countries or in transition towards the innovation-driven stage **Apparent comparative advantage:** Government decision to strengthen particular fields of science, including by the use of the European structural funds but also of the Framework Programmes in specific cases	**Strong Science — Strong Technology** *Rationalisation* Innovation-driven countries (or in transition towards the innovation-driven stage) **Apparent comparative advantage:** Government decision depending on sustainability of specialisation (whether the industries experience growth or decline) European Framework Programmes funding salutary
Modest	**Modest science — Modest technology** *Capacity building* Factor-driven countries or in transition towards the efficiency-driven stage **Latent comparative advantage (other than S&T):** Government attention towards specialisation in the long-run, based on the eventual presence of raw materials, etc. Structural funds could be salutary **Unknown comparative advantage:** Government decision on general horizontal framework conditions for private sector R&I	**Strong science — Modest technology** *Transformation or the reallocation of resources* Innovation-driven countries **Latent comparative advantage:** Government decision to strengthen relevant technology by (catalytic) public procurement for innovation and other technology field specific framework conditions for private R&I An alternative strategy to reallocate resources from unmatched scientific fields to the areas that support existing technology-industry strengths European Framework Programmes instrumental for new and emerging technologies

The left-hand upper quadrant, characterised by modest science and strong technological developments will be part of the rationalisation process. The apparent comparative advantage is given by a successful technologicaly-based industry in place, the role of the government being to orient science in order to better sustain existing technological development. This situation is overall characteristic of the catching-up countries, being countries either in the efficiency-driven stage of economic development, or in transition towards the innovation-driven stage (following Porter's rationale). It is the case of countries with a substantial amount of foreign direct investments (FDI) for technology and innovation-related activities. A government decision to increase science capabilities where the technology-based industry is already strong depends mainly on political will. The complementary use of European Cohesion Funds, with its recent focus on smart specialisation by orienting EU structural funds towards research and/or innovation-driven sectors, remains instrumental in raising the quality of science in domains/sectors that are already experiencing a certain technological dynamism at the national level. A strategic and focused use of FP7 and the upcoming Horizon 2020 programme is also relevant in this situation for fields of science where the research results indicate a certain degree of good quality.

The left-hand lower quadrant of the graph is characterised by both modest science and modest technology, reflecting a situation that is very likely specific to the factor-driven economies, or those in transition towards the efficiency-driven stage, as they are defined by Porter. To be able to progress towards the stage of efficiency-driven economies, from the point of view of technology adoption, these countries must endeavour to attract FDI for technologically-based economic activities, with a view to ensuring the overall efficient functioning of the economy. This is a situation with unknown comparative advantage given by both weak industry and weak science. More horizontal measures, such as improving the overall business environment and entrepreneurial skills in universities, will keep the potential open for eventual future specialisation. Nevertheless a latent comparative advantage can still be present, given by the existence of other factors, such as raw materials. This could trigger a government decision for specialisation, though with potential results to be expected at a more distant horizon than compared to the situation where scientific specialisation is already there.

THE CASE OF ROMANIA FOR THE FIELD OF FOOD, AGRICULTURE AND BIOTECHNOLOGIES

A serious decline in the food and agriculture field after 1990 led to a lack of specialisation in science and industry, despite the existence of massive potential in terms of natural resources and primary production factors. This situation is rather unique in the region, as countries with similar economic patterns, such as Bulgaria, Turkey and Croatia, but also Hungary, Slovakia, the Czech Republic and Poland, continued to support the field of food and agriculture after the fall of communism. As developments can often be rebooted bottom-up in the case of existing latent comparative advantages, over the last decade the quality of science in this field rose spectacularly, accompanied by a high growth in the number of publications in the field of biotechnologies. However, the country has not yet reached a critical mass of publications to be specialised in these fields, and related technologies are not present. In this context, it will be instrumental if the government takes decisions to further boost science in the fields of food, agriculture and biotechnology, while at the same time putting in place instruments aimed at attracting/developing related technologies in the field, such as public procurement for innovation, etc. Coupled with a large domestic economy (over 30% of the population is still employed in the food and agriculture industry), the possibility of raising the industry position in the global value chain is worth further exploration.

The right-hand upper quadrant is related to domains that benefit from both strong scientific capabilities and strong technological developments. This is generally the case with innovation-driven economies, which overall tend to be successful in transferring knowledge from science to technology, basing their technological strengths both on very good and excellent quality of national science and on excellent science produced elsewhere. A smart specialisation process in these sectors would simply need to take into account whether the industries are experiencing growth or decline, which is related to the sustainability of a specialisation. In this case, a better match between science and technology industries could help the industry to either maintain a competitive edge in the sector, or regain a competitive advantage by investing in R&D. Both European funding instruments of Cohesion Funds and/or Horizon 2020 (European Framework Programmes) can be complementary to the national funding for given sectors, case by case.

The right-hand lower quadrant appears empirically to be linked more to advanced, innovation-driven countries, with two different possibilities: on the falling side, this situation of strong science but modest technology can be the result of a decline in a technology that was once strong (an example can be the automobile industry in the UK); in this case, without an eventual policy intervention, the decline in technology will likely trigger a decrease in science specialisation and quality, over longer periods of time. Reallocation decisions moving funding between scientific fields may save resources and enhance efficiency. Where the industry is weakened but the science is still strong, government measures become more complex and the results rather indirect. Improving different framework conditions for private R&I becomes essential, such as promoting public procurement for innovation in the respective field, or even innovation-oriented state aid for a given sector of the economy provided this is in line with European regulations.

On the rising side, this last quadrant reflects a potential for economic transformation triggered by knowledge or radical innovation. This would, however, require a vigorous 'diamond', including potential for converging technology development. Emerging fields such as nanosciences or renewable energies responding to the challenge of climate change are typical examples in this case. Overall policies addressing societal challenges, challenge-driven innovation and focusing on lead markets are promising avenues for such a transformation, using instruments such as public procurement, advanced regulation and strict standards in the given field. The critical mass and the strategic and global nature of the EU Framework Programme and its successor Horizon 2020 have the potential to support innovation-driven countries in their transformative science and technology efforts (see the annex), for instance the high level of participation of Germany in FP7 projects in the field of nanotechnologies — over 80% of projects in this field benefit from German participation. In this context it is worth emphasising that ***the Framework Programme offers potential short-cuts for countries still in the phase of pursuing their way towards innovation-driven economies***, by facilitating the creation of networks and strategic knowledge spillover between Member States at various stages of development.

3. Empirical data on co-developments of science and technology at a national level and the use of FP7 funding

3.1. Overall correlation between national S&T strengths and participation in FP7

European funding instruments such as FP7 have the capacity to leverage S&T performance at a national level. FP7 and the future Horizon 2020 programme act as facilitators for the creation of European networks, and therefore will ensure the access to excellent science as well as to collaboration with top European researchers. This can be considered as a short-cut for improving the scientific capabilities of countries still pursuing their ways towards innovation-driven economies, in the research fields that have already reached a good level of quality enabling researchers to be successful in FP7 calls. The Framework Programme is also of particular importance in the framework of economic transformation, with its topics and programmes aimed at seeking solutions to pressing societal challenges as well as promoting frontier research.

The table below shows a relative correlation between S&T capabilities at a national level and the use of funding from the 7th Framework Programme for a number of fields. The field of health displays the greatest correlation between S&T national specialisation and financial success in FP7. Other fields present an overall correlation of FP success with the technological strengths at a national level. These are: food, agriculture and fisheries; biotechnology; materials (excluding nanotechnologies) and security. Finally, for nanosciences and new production technologies, there is a noticeable correlation between scientific strengths at home and participation in FP7.

Health	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	**0.705**	0.496	0.553	0.306
Technology strength (per inventor)	0.587	0.345	0.462	0.214
Technology strength (per applicant)	**0.632**	0.399	0.500	0.250

Information and Communication Technologies	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.577	0.333	0.285	0.081
Technology strength (per inventor)	0.442	0.196	0.239	0.057
Technology strength (per applicant)	0.449	0.202	0.257	0.066

Food, Agriculture and Fisheries	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.516	0.267	0.233	0.054
Technology strength (per inventor)	**0.728**	0.531	0.380	0.144
Technology strength (per applicant)	**0.682**	0.466	0.350	0.123

Environment	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.350	0.123	0.202	0.041
Technology strength (per inventor)	0.454	0.206	0.142	0.020
Technology strength (per applicant)	0.431	0.186	0.156	0.024

Energy	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.397	0.158	0.148	0.022
Technology strength (per inventor)	0.580	0.337	0.082	0.007
Technology strength (per applicant)	0.578	0.334	0.134	0.018

Biotechnology	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.087	0.007	-0.185	0.034
Technology strength (per inventor)	**0.885**	0.784	**0.795**	0.632
Technology strength (per applicant)	**0.856**	0.732	**0.751**	0.564

Nanosciences and Nanotech	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	**0.666**	0.444	0.473	0.223
Technology strength (per inventor)	0.580	0.336	0.471	0.222
Technology strength (per applicant)	0.583	0.340	0.487	0.237

Materials (excluding nanotech)	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.575	0.330	0.076	0.006
Technology strength (per inventor)	**0.789**	0.623	0.312	0.097
Technology strength (per applicant)	**0.756**	0.572	0.333	0.111

New Production Technologies	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	**0.624**	0.389	0.351	0.123
Technology strength (per inventor)	0.529	0.280	0.222	0.049
Technology strength (per applicant)	0.561	0.315	0.287	0.082

Construction and Construction Technologies	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.492	0.242	-0.079	0.006
Technology strength (per inventor)	0.550	0.303	0.081	0.007
Technology strength (per applicant)	0.477	0.228	0.068	0.005

Sustainable surface transport	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.467	0.218	0.035	0.001
Technology strength (per inventor)	0.434	0.188	0.087	0.008
Technology strength (per applicant)	0.425	0.180	0.127	0.016

Aeronautics and air transport	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.273	0.075	0.024	0.001
Technology strength (per inventor)	0.334	0.111	-0.076	0.006
Technology strength (per applicant)	0.341	0.116	-0.075	0.006

Other Transport Technologies	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.058	0.003	-0.201	0.040
Technology strength (per inventor)	0.138	0.019	-0.112	0.013
Technology strength (per applicant)	0.133	0.018	-0.023	0.001

Security	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.017	0.000	-0.392	0.153
Technology strength (per inventor)	**0.625**	0.390	0.048	0.002
Technology strength (per applicant)	**0.644**	0.414	0.065	0.004

Source: DG Research and Innovation — Economic Analysis Unit

Data: DG Research and Innovation — Economic Analysis unit; Science Metrix — Canada, based on Scopus data; Univ. Bocconi - Italy, based on WIPO-PCT applications

Note: Technological strength refers to total number of patent applications (by investor's or applicant's country) per GDP in billion PPS, for the period 2000-2010. Scientific strength refers to the share of publications in the top 10% most cited publications of total publications of a country.

Interestingly enough, for half of the analysed FP7 thematic priorities there is no significant correlation between S&T capabilities at a national level and the participation in the Framework Programme. This means that there is sufficient manoeuvring room for Member States to further build on their home strengths when participating in the Horizon 2020 programme (which is the follow-up programme to FP7), and the other way round, i.e. to use this European instrument as a way of leveraging their S&T strengths at home.

Some countries perform better than others with respect to the correlation between S&T capabilities at a national level and participation in FP7. Extensive data by fields (not seen in the table) show that whereas there is a significant correlation between science at home and participation in FP7 for most European countries in the field of health, in other domains the correlation is less evident, with differences between countries. In the field of food, agriculture and fisheries, the Nordic European countries (Denmark and Finland), as well as the Netherlands, Belgium and Ireland show particularly good use of national technological resources by a higher participation in FP7. The same goes for the field of biotechnologies, broadly with the same top countries: Finland, the Netherlands, Belgium and Ireland, as well as Slovenia. For nanosciences and nanotechnologies, yet again the Nordic countries (Finland, Sweden, Denmark) are prominent, but Switzerland, Ireland, Belgium, Slovenia, and the Czech Republic are also successfully building on their home scientific capacity when participating in FP7. And finally, in the field of materials (excluding nanotechnologies) there are several countries whose participation in FP7 is very successful when comparing to their technological strengths at home: Switzerland, Belgium, Denmark, Slovenia, Ireland, Italy and Spain are among these countries.

3.2. Two examples of analysis at a country level: the UK and Romania

The starting question when analysing a co-development of science and technology at a country level is whether there is any co-development of science and technology at all. Follow-up questions are then whether the participation in FP7 is related to the existing national S&T specialisation and dynamics, and/or to the quality of science. There can be domains with certain strengths at a national level in terms of S&T specialisation, high growth and excellent quality of science, but with insufficient participation in FP7 when compared to the country's S&T capabilities. Here, government intervention would make sense to provide support for those fields/institutions that show good capabilities at national level, in order to have them become more successful in the FP programmes. Of course, there can also be the reverse situation, with successful domains/institutions in FP7, but no specialisation at a national level. Here the intervention of the government would be expected to be the other way round, by looking closer at fields that prove to be internationally successful (in this case in FP7) when evaluating the strengths of research performance, and supporting research fields at a national level.

3.2.1. The example of the UK

Data show that the UK is successful overall in transferring knowledge from science to technology in most of the analysed fields. In addition, there has been a general coherence in the dynamics of co-specialisation in S&T over the last decade, where a simultaneous growth in both publications and patents can be in various fields (except obviously for socio-economic sciences and humanities, where there are no patents). Another positive aspect is reflected by the general higher level of specialisation in technology compared to science, which can be interpreted in the sense that the technological performance of the country is based both on national science with an overall excellent quality and also on science coming from abroad.

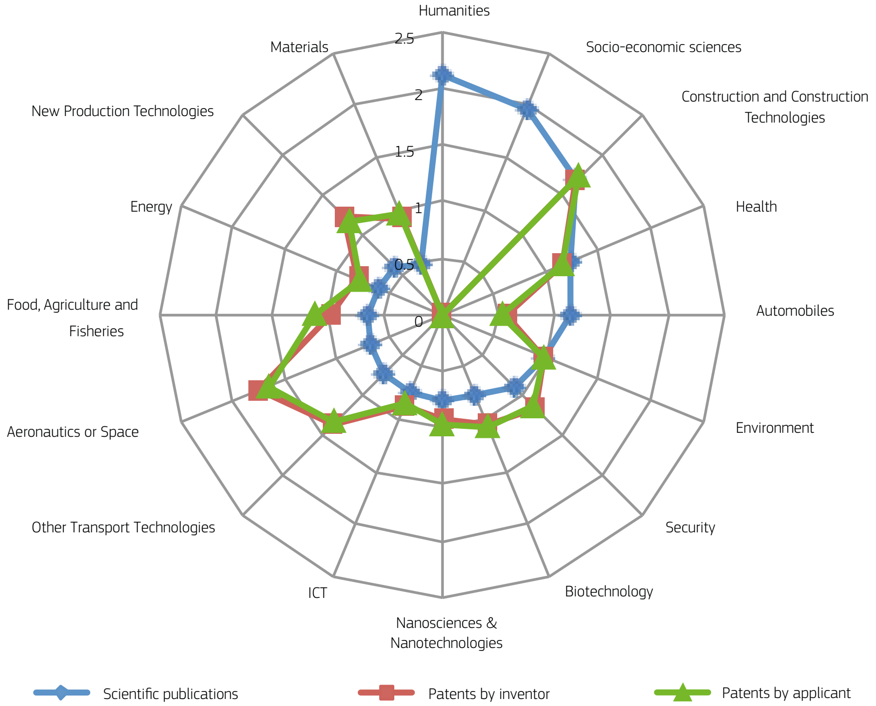
Regarding specialisation, there is a good match between the scientific and technological performance at a country level in the fields of *construction, health, environment* and *security*, reflecting a particularly good absorption of science into technological products for these fields. Three out of the four fields are also among the most successful in FP7, namely *health, environment* and *security*. The same goes for the overall research field of social sciences and humanities, where there is a strong specialisation in publications at a national level coupled with a high success in FP7. There is an overall significant coherence among S&T co-specialisation at home and participation in FP7, showing that the UK successfully builds on its national S&T capabilities when participating in the European Framework Programme.

Going deeper into the analysis, the greatest technological specialisation of the UK appears to be in the field of aeronautics. This is not matched by a similar specialisation in science, though there has been a sufficiently high growth in both publications and patents over the last 10 years, and the quality of science is very good. High growth rates can also be noticed in the fields of ICT and nanosciences and nanotechnologies, showing the potential for increasing specialisation in these fields in the future.

A specific case is the field of automobiles, where the science created in this field is not sufficiently translated in technology. In addition, the field appears to be quite static, without spectacular growth rates in S&T over the last decade and with a rather linear quality of science over the same period — just above the world average (and second-to-last compared to the other research fields in the UK). According to the theoretical model presented at the beginning of the paper, a certain decline in this industry might produce a similar decline in the quality of science in the longer term if policies are not put in place to promote the revival of the automobile industry. It is worth mentioning that the sector might be revitalised by the current orientation of the UK Government towards a low-carbon future and, in this context, towards a desired shift to ultra-low carbon vehicles.

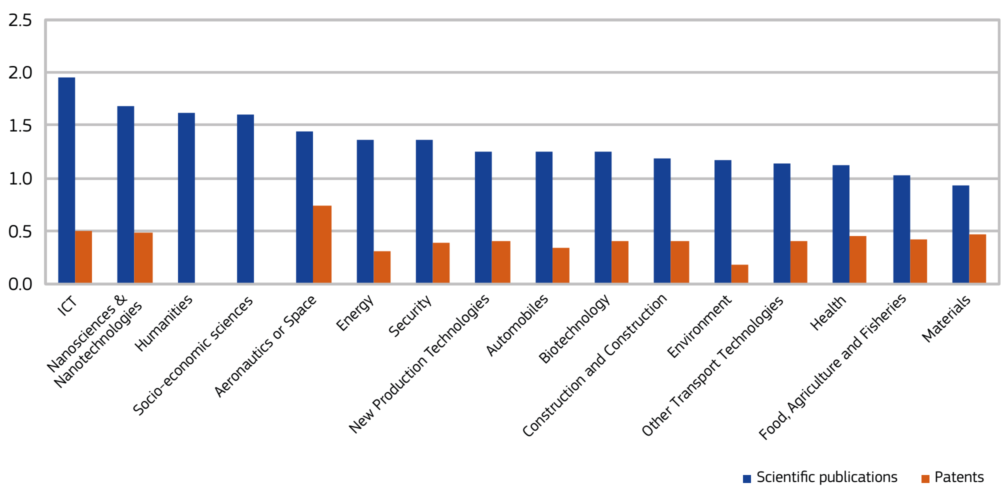
Finally, the field of food, agriculture and biotech is among the fields where the UK is most successful in FP7. However, this is not matched by a specialisation in this research field at a national level, so this field could be looked at more closely when evaluating the strengths of research performed at a national level.

United Kingdom S&T National Specialisation in FP7 thematic priorities, 2000–2010



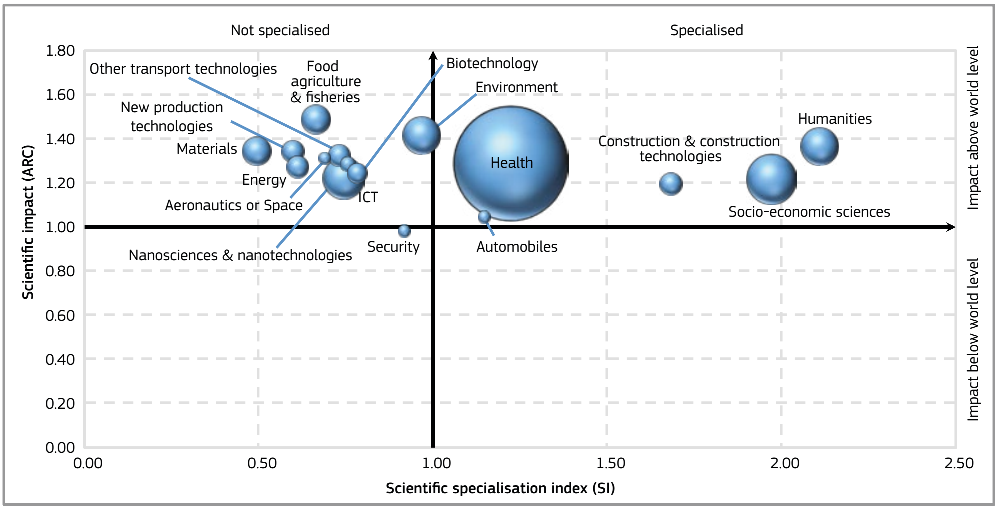
Source: DG Research and Innovation — Economic Analysis Unit.
Data: Science Metrix — Canada, Univ. Bocconi — Italy.
Notes: Values over 1 show specialisation, under 1 lack of specialisation.
Patents in 'Aeronautics or Space' refer only to 'Aeronautics' data.
For the thematic priorities with fewer than 5 patent applications over 2000–2010, the RTA is not taken into account.

Growth Index of United Kingdom publications (in Scopus) and patents (WIPO), 2000–2010



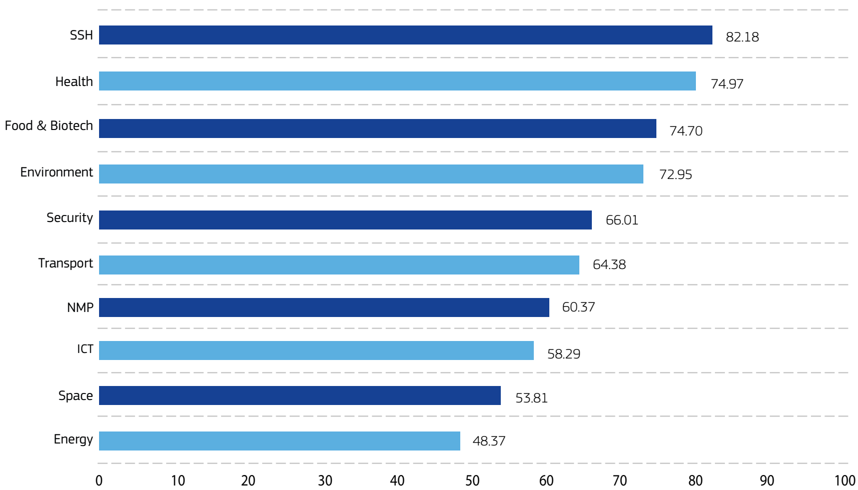
Source: DG Research and Innovation — Economic Analysis Unit.
Data: Science Metrix — Canada, based on Scopus data; Univ. Bocconi — Italy, based on WIPO-PCT applications.
Note: Patents in 'Aeronautics or Space' refers only to 'Aeronautics' data.
The growth rate in the number of patents refers to the periods 2000–2002 and 2003–2006.
The growth rate index of the publications refers to the periods 2000–2004 and 2005–2009.

Positional analysis of United Kingdom publications in Scopus by FP7 (specialisation versus impact), 2000–2010



Source: DG Research and Innovation — Economic Analysis Unit.
Data: Science Metrix — Canada, based on Scopus.
Notes: Scientific specialisation includes 2000-2010 data; the impact is calculated for publications from 2000–2006, citation window 2007–2009.

Share of total projects where United Kingdom has at least one participant, by FP fields



Source: DG Research and Innovation.
Data: DG Research and Innovation — Economic Analysis unit.

Country	Co-specialisation in science and techno-logy 2000–2010	Fields with significant growth rates in both science and technology 2000–2010	Excellence in science	Most successful fields in FP7
UK	Construction **Health** **Environment** **Security** **Socio-economic sciences and humanities** (only publications)	ICT Nanoscience and nanotechnologies Aeronautics	All fields	**Socio-economic sciences and humanities** Food, agriculture and biotechnology **Environment** **Health** **Security**

3.2.2. The example of Romania

In the case of Romania there is no overall correlation between specialisation in science and specialisation in technologies. The science base is not generally of sufficiently good quality to support knowledge transfer towards industry through technologies, at the same time the country does not yet benefit from sufficient FDI inflows for technological activities, which would help shape a more coherent industrial specialisation. In this context, it is critical to improve the overall framework conditions for business innovation, including the IPR framework, access to capital by innovative firms, public procurement for innovation, entrepreneurship skills, etc.

Within the whole spectrum of the analysed fields, there are three main fields with co-specialisation in both S&T: ICT, new production technologies and energy. This shows a certain degree of knowledge transfer from science to technologies in these three fields, making them important candidates for a smart specialisation strategy.

In the fields of **ICT and New production technologies**, the co-specialisation in S&T has been backed up by visible growth rates in both publications and patents over the last decade, likely due to the existence of firms on the Romanian market absorbing the scientific results in related industries. Policy decisions should be oriented towards further increasing the quality of science publications, which is well under the world average in both fields. One avenue for doing this is to support better participation in the Horizon 2020 programme of projects, especially in the field of ICT, where Romanian participation is currently very low (Romania participates in only 4.79% of total ICT projects in FP7).

The field of **energy** is more static as regards technologies compared to the two fields above, with a low number of patents over the last decade. On the other hand, the research results in the energy field are among the best research fields in Romania, coming in just under the world average regarding the quality of publications. Here the decisions could follow two directions: promoting specific framework conditions such as public procurement or grants for innovative solutions in the field with the potential of unleashing competitive advantages, as well as further improving the quality of science. One avenue for doing this is by supporting increasing success in the EU Framework Programmes. Participation in FP7 is pretty low, with a participation in only 5.56% of European projects in the field of energy. To give some examples of potential at an institutional level, University Politehnica of Bucharest and University Politehnica Timisoara are highly specialised (493 publications, respectively 89 publications indexed in Scopus in the period 2007-11) but are not well-connected in national or international networks. The Romanian Academy has also had some publications in the field (68 over the same period).

Construction and construction technologies is a field that presents clear development potential. Whereas a noticeable specialisation in technology can already be seen — it is the research field that has grown most over the last ten years. However, the overall quality of science needs to be considerably improved.

The **environment** field also presents a certain dynamism, with specialisation in technologies and high growth rates in science combined with the country having the highest participation in FP7 (Romania is present in 13.77% of environmental projects). At an institutional level, the most success in FP7 is enjoyed by the University of Bucharest and the National R&D Institute for Geology and Marine Geo-Ecology (GeoEcoMar), both from Bucharest.

The field of **automobiles** is stronger compared to other fields when looking at technologies, showing both specialisation and high growth rates of patents over the last 10 years. However, this is not sufficiently matched by science results, with the quality of publications needing substantial improvement. This seems to be a situation of apparent comparative advantage, with industrial development in place, but with the science side needing further improvements.

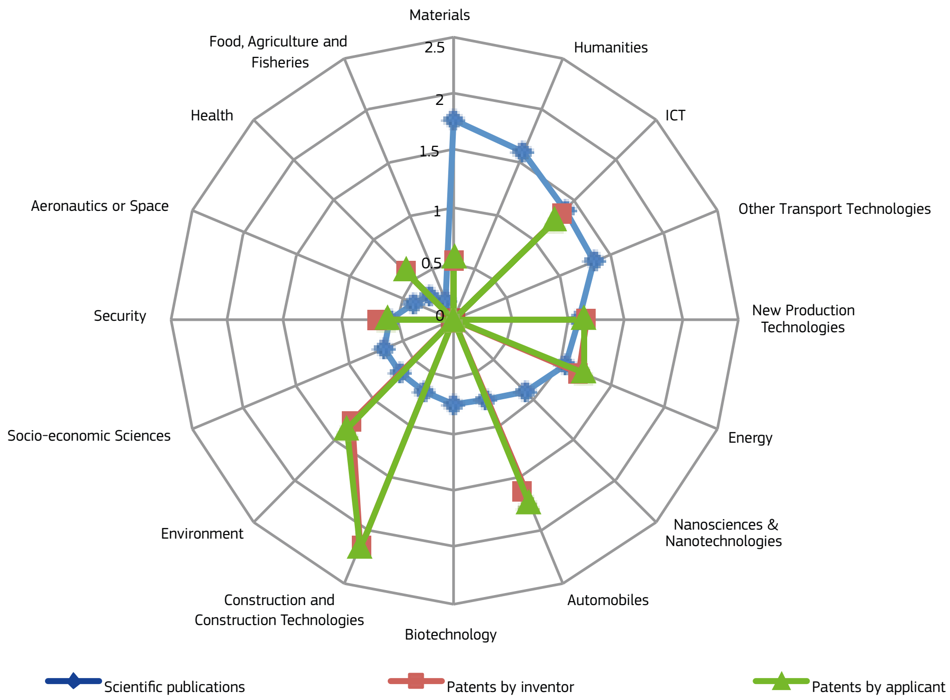
The fields of **food, agriculture and fisheries** and **biotechnologies** point to interesting developments. Whereas the former has the best quality of publications compared to all the other research fields of Romania, the latter has been growing massively in terms of number of publications over the last 10 years. However, neither of these sectors is substantially backed up by technologies. Framework conditions for private R&I will be instrumental in these two fields in order to unleash the latent comparative advantages.

The field of **other transport technologies** benefits from considerable specialisation in science, matched by a good quality of publications (just above the world average) and around 10% participation in the FP7 projects in the field. However, it is not matched by any specialisation in technologies, and is also the only field with negative growth rates of patents over the last 10 years. Without a strong push of knowledge transfer towards industry applications, the research capacities in this field are likely to decline in the future, as is already happening in the field of materials.

There are severe mismatches between scientific and technological developments in the field of **materials**. Despite considerable specialisation in science, the quality of publications remains rather low, and is deteriorating. The research field has been very static over the last ten years and not at all matched by technologies. In other words, the industry is failing to absorb the knowledge created in the field of materials. This may well be due to the fact that the chemical industry in Romania has substantially declined over the last decade. Without an industrial revival of the field, research will likely continue its decline.

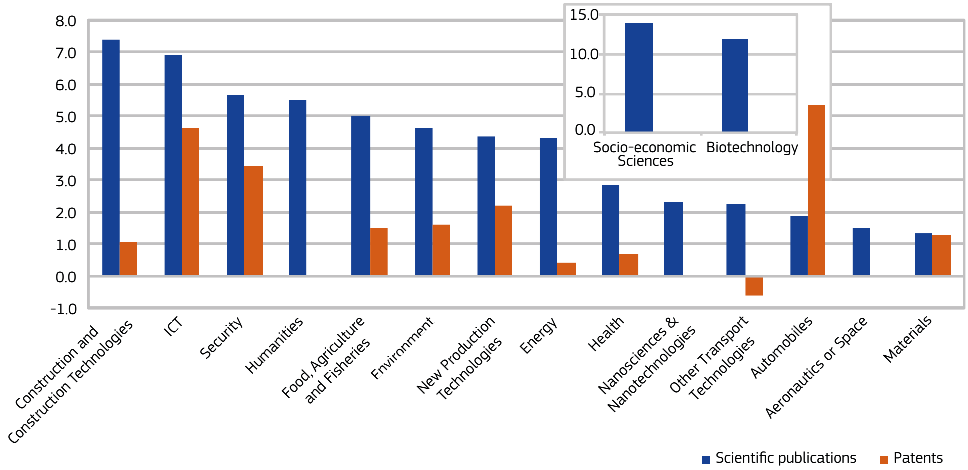
Finally, the fields where there is no co-specialisation in S&T, no growth over the last decade and no science of substantial quality are **nanosciences and nanotechnologies, aeronautics and health.**

Romanian S&T National Specialisation in FP7 thematic priorities, 2000–2010



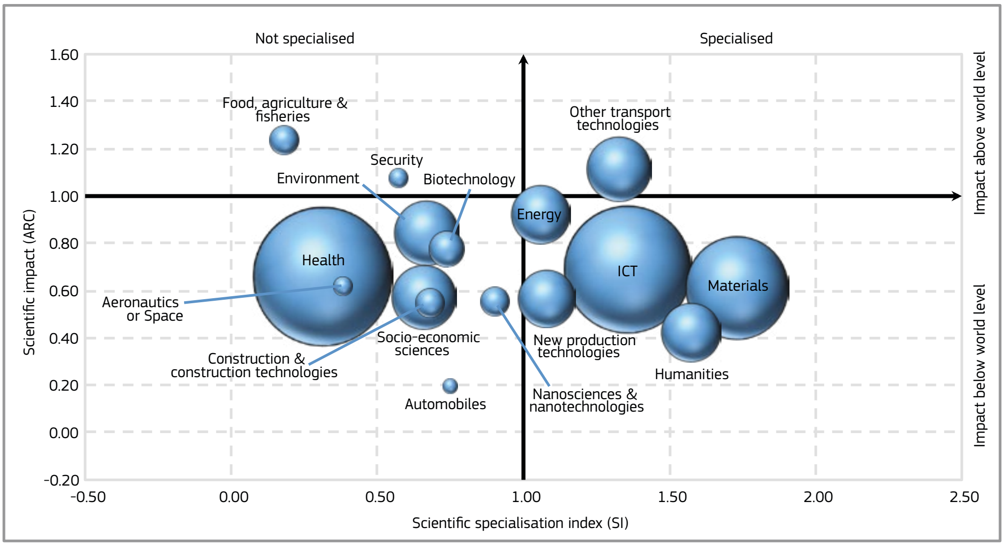
Source: DG Research and Innovation — Economic Analysis Unit.
Data: Science Metrix — Canada, Univ. Bocconi - Italy.
Notes: Values over 1 show specialisation, under 1 lack of specialisation.
Patents in 'Aeronautics or Space' refers only to 'Aeronautics' data.
For the thematic priorities with fewer than 5 patent applications over 2000–2010, the RTA is not taken into account.

Growth Index of Romanian publications (in Scopus) and patents (WIPO), 2000–2010



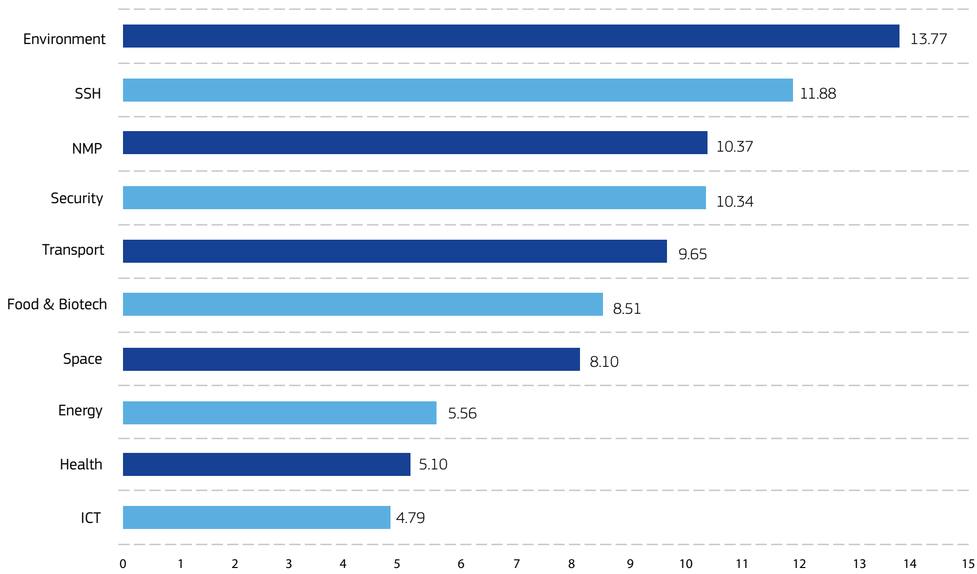
Source: DG Research and Innovation — Economic Analysis Unit.
Data: Science Metrix — Canada, based on Scopus data; Univ. Bocconi — Italy, based on WIPO-PCT applications.
Note: Patents in 'Aeronautics or Space' refer only to 'Aeronautics' data.
The growth rate in the number of patents refers to the periods 2000–2002 and 2003–2006.
The growth rate index of the publications refers to the periods 2000–2004 and 2005–2009.

Positional analysis of Romanian publications in Scopus by FP7 (specialisation versus impact), 2000–2010



Source: DG Research and Innovation — Economic Analysis Unit.
Data: Science Metrix — Canada, based on Scopus.
Notes: Scientific specialisation include 2000–2010 data; the impact is calculated for publications from 2000–2006, citation window 2007–2009.

Share of total projects where Romania has at least one participant, by FP fields



Source: DG Research and Innovation.
Data: DG Research and Innovation — Economic Analysis Unit.

Country	Co-specialisation in science and technology 2000–2010	Fields with significant growth rates in both science and technology 2000–2010	Excellence in science	Most successful fields in FP7
Romania	ICT **New production technologies** Energy **Humanities** (only publications)	ICT Security Biotechnologies (only publications) Construction (only publications) Automobiles (mainly patents)	Food & agriculture Other transport technologies Security Energy (is increasing in quality)	Environment Socio-economic sciences and **humanities** Security Nanomaterials-**new production technologies**-construction

Annex 1 presents an interesting empirical analysis of S&T co-developments at a national level by groups of countries with similar characteristics, as well as several other examples of possible analysis at a national level for Spain and Sweden.

Conclusions

To conclude, this paper considered four types of S&T co-developments at a national level, based on existing strengths in science and technology. The identified types were: *strong technology and strong science; strong technology and modest science; modest technology and strong science; and modest technology and modest science*. Adopting the general assumption that innovation-driven countries would benefit from an overall excellent quality of home science leveraging their technological performance, the paper analyses the dynamics of the four different types of co-development by placing them in the perspective of economic rationalisation vs. economic transformation, and by taking into account the level of economic development of the countries and their comparative advantages. Finally, the paper identifies the role of government for each of the four situations and comes to the conclusion that government intervention will be crucial in the short and medium-term, primarily in the situation of mismatches (i.e. strong technology and weak science or vice versa).

The existence of strong technologicaly-based industries will reveal an apparent comparative advantage at a national level. The role of government here will be to rationalise resources by fostering fields of science able to sustain existing technology-based industries. Where the science is already strong (this is generally the case for countries that are already innovation-driven), government decisions would depend mainly on sustainability of specialisation, i.e. whether the industries experience growth or decline. Where the science is weak but technology is strong, which is a situation generally specific to catching-up countries, fostering the respective science fields will be a valid choice as part of the smart specialisation process.

In cases of modest technology, government decisions could become more complex. Where the modest technology is accompanied by modest science, the government could be expected to place an emphasis on overall horizontal framework conditions for private sector R&I, with a view to keeping the possibilities for future specialisation open. In addition, the government might decide to support development in fields where there are latent comparative advantages other than S&T, e.g. given by the existence of raw materials.

Where modest technology is associated with strong science, this can be the result of a decline in a technology that once was strong, which will likely also trigger a decline in science over longer periods of time; reallocation decisions moving funding between scientific fields may save resources and enhance efficiency. However, the situation of modest technology and strong science may also reflect the important potential of economic transformation triggered by knowledge/radical innovation. Overall policies addressing societal challenges, challenge-driven innovation and focus on lead markets are promising avenues for such transformation, using instruments such as public procurement, regulation, standardisation, etc.

European funding instruments have the capacity to leverage S&T performance at a national level. On the one hand, structural funds are crucial for catching-up countries in order to improve science quality in those domains in which the technology is already well-developed, as well as to foster S&T capabilities in fields with other latent comparative advantages (e.g. raw materials). On the other hand, FP7 and the future Horizon 2020 programme will act as facilitators for participation in European networks, ensuring access to excellent science, as well as to collaboration with top European researchers. Framework programmes can be used as a short-cut for improving the scientific capabilities of countries still striving towards innovation-driven economies, in research fields that have already reached a good level of quality at a national level, enabling researchers to be successful in FP7 calls. Last but not least, the Framework Programme takes on particular importance in the framework of economic transformation, aiming through its topics and programmes to address pressing societal challenges as well as to promote frontier research.

Finally, the empirical analysis carried out in this paper shows that, whereas there is a certain degree of correlation between the S&T strengths at a national level and participation in the European Framework Programmes, there is still room for further improvement, both at an overall level and when looking at individual countries. This is also reflected by the two examples of analysis at a country level: the UK and Romania.

BIBLIOGRAPHY

Breschi S. *Country and regional technological profiles* (2011) — Report of the study 'Measurement and analysis of knowledge and R&D exploitation flows, assessed by patent and licensing data'. The study was carried out by KU Leuven (coordinator), Bocconi University, Italy and Technopolis, Vienna and financed under the European 7th Framework Programme, DG RTD Unit C6 Economic Analysis and Indicators.

Callaert J., Vervenne, J-B., Van Looy, B., Magerman, T., Song, X. and Jeuris, W., *'Patterns of Science-Technology Linkage*', (2013, forthcoming) — Report of the study 'Measurement and analysis of knowledge and R&D exploitation flows, assessed by patent and licensing data', carried out by KU Leuven (coordinator), Bocconi University, Italy and Technopolis, Vienna, Austria and financed in under European 7th Framework Programme, DG RTD Unit C6 Economic Analysis and Indicators.

Campbell, D., Picard-Aitken, M., Côté, G., Ventimiglia, A., Roberge, G. and Archambault, E. *Country and Regional Scientific Production Profiles* (2012) — Report of the study 'Analysis and Update of Bibliometrics Indicators', carried out by Science Metrix, Canada, and financed under the European 7th Framework Programme, DG RTD Unit C6 Economic Analysis and Indicators.

Castells, M., 'The Information Age, Economy, Society and Culture' *Volume I: The Rise of the Network Society,* Blackwell Publishers Ltd, Oxford, UK, 1996.

ERA-PRISM FP7 project: 'Policies for Research and Innovation in Small Member States to Advance the European Research Area', *2011 Report on Funding Frameworks, Comparative analysis and Identification of best practices;* project coordinator: Jennifer Harper from the Malta Council for Science and Technology.

European Commission, Innovation Union Competitiveness Report, 2011,
http://ec.europa.eu/research/innovation-union/index_en.cfm?section=competitiveness-report&year=2011

European Commission, Innovation Union Scoreboard, 2013,
http://ec.europa.eu/enterprise/policies/innovation/files/ius-2013_en.pdf

Foray, D., David, P.A. and Hall, B., 2009, 'Smart specialization — The concept', *Knowledge Economists Policy Brief No 9*,
http://ec.europa.eu/invest-in-research/monitoring/knowledge_en.htm

Malerba, F., 'Sectoral systems of innovation and production', *Research Policy 31,* 2002, pp. 247–264.

Murmann, J.P., 'The co-development of industrial sectors and academic disciplines', Science and Public Policy 40, 2013, pp. 229–246.

Porter, M.E., The Competitive Advantage of Nations, New York, Free Press, 1990.

Schön, L., 'Technological Waves and Economic growth — Sweden in an International Perspective 1850-2005', Paper 2009/06 Circle, Lund University, 2009.

Stiglitz, J., Free fall, New York, W.W. Norton & Company, 2010.

Verspagen, B., 'Economic growth and technological change. An evolutionary interpretation', Eindhoven Centre for Innovation Studies (ECIS), The Netherlands, 2000.

World Economic Forum (2012), 2012-2013 Global Competitiveness Report,
http://reports.weforum.org/global-competitiveness-report-2012-2013

World Bank, 'Research and Innovation for Smart Specialisation Strategy: Concept, Implementation Challenges and Implications', Draft 25 June 2012, prepared as a background note for the Workshop: 'Smart Investment for Smart Specialisation: A Regional Practitioners' Exchange' — Warsaw, Poland 27–28 June 2012.

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

- one copy:
  via EU Bookshop (http://bookshop.europa.eu);
- more than one copy or posters/maps:
  from the European Union's representations (http://ec.europa.eu/represent_en.htm);
  from the delegations in non-EU countries (http://eeas.europa.eu/delegations/index_en.htm);
  by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm) or
  calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (http://bookshop.europa.eu).

Priced subscriptions:

- via one of the sales agents of the Publications Office of the European Union
  (http://publications.europa.eu/others/agents/index_en.htm).

European Commission

Co-development of Science and Technology at a National Level and the Use of European Funding Instruments. Innovation Union. Competitiveness papers. Issue 2013/4

Luxembourg: Publications Office of the European Union

2013 — 27 pp. — 17.6 x 25 cm

ISBN 978-92-79-31234-2
doi:10.2777/30492

KI-03-13-355-EN-N

The article focuses on co-developments of science and technology at a national level, considered in the broader framework of economic rationalisation versus economic transformation. The matching of science with technology is part of a rationalisation effort aimed at ensuring the optimal economic impact of existing resources. An evidence-base analysis identifying the level of matching will enable strategic policy thinking on possible resource re-allocations, specialisation or focused international science and technology cooperation. Under certain conditions, a mismatch can also have a transformative potential, with science and technology contributing to a broader industrial structural change. The paper takes both a dynamic view of countries, considering the various stages of their economic development, and a dynamic view of sectors linked to the concept of smart specialisation. Four types of co-developments in science and technology have been identified, accompanied by indications of desirable policy decisions in each situation, both at a national level and by using the European funding instruments.

The empirical work backs up the analytical framework, providing evidence on co-developments of science and technology at a national level and through the use of the 7th European Framework Programme. The analysis is done by groups of countries with similar characteristics in terms of knowledge capacity, on one hand, and the economic structure prevailing in the system, on the other hand. The paper also includes a detailed analysis of a limited number of European countries. The annex provides extensive relevant data for 35 countries, which can be used by those interested in further analysis of their national S&T co-developments.

Studies and reports

Publications Office

ISBN 978-92-79-31234-2

9 789279 312342

doi:10.2777/30492